Annual Technical Report

Summary Descriptions of Research
for the period June 1, 1992
through May 31, 1993

Institute for the Study of Human Capabilities

URI - AFOSR #90-0215

Poplars Research and Conference Center
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This report describes work in several areas, all of which focus on problems of skilled human performance. The Institute's investigators are primarily active in the fields of human cognition and decision making, and in sensory processes, including vision, audition, and touch; research in those areas represent the major content of this report. Specific projects continue to focus on human subjects' abilities to use information obtained from visual, auditory, and tactile displays. Both empirical and theoretical studies continue to be conducted. Studies of human cognition include a new theory of the limits of human auditory signal detection, the discovery of a common source of variance in auditory and visual speech perception (lip-reading), automatization of perceptual processes, and automatization as a mechanism for overcoming attentional limitations.

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Annual Technical Report

Summary

This Annual Technical Report of the URI/AFOSR-supported Institute for the Study of Human Capabilities, at Indiana University, describes work done from June 1, 1992 through May 31, 1993. The Institute currently consists of thirteen affiliated laboratories, in which research is conducted by eighteen faculty investigators and a considerably larger number of graduate research assistants, technicians, programmers, and other staff members. One of the primary goals of the Institute is to provide enhanced opportunities for interactions among these investigators, whose appointments are in six departments (Psychology, Speech and Hearing Sciences, Visual Science, Linguistics, Mathematics, Medical Science) and three schools or colleges of the University (College of Arts and Sciences, School of Optometry, School of Medicine). Another goal is to familiarize scientists who conduct basic research on cognition, sensory processing, and decision making, with current problems in the field of human factors, or human engineering. The Institute is also available as a source of technical or scientific advice for researchers in government or industry who are working in areas related to those represented in its laboratories.

We continue to make significant progress toward our long-term goals. The Institute maintains an inter-laboratory, work-station based computer network, using the UNIX operating system. This network has been in operation for the past five years and is now in regular use for the exchange of information and, in several laboratories, for data analysis, graphics, and modeling. Other ways that the Institute-affiliated faculty interact are by attending Institute-sponsored seminars presented by visiting scientists, through other interactions with these visitors, and through collaborative research. Funds made available through the Institute continue to be used to maintain, repair, and in some cases upgrade research apparatus in the affiliated laboratories. The Institute employs several part-time technicians, programmers, and graduate student research assistants who conduct research under the direction of the faculty investigators. One half-time computer systems administrator is employed who maintains the inter-laboratory computer network.

During this past year we devoted considerable time to an evaluation of the Institute's activities during its first six years of operation. A great deal has been accomplished, as described in the following report and those that preceded it. It was recognized, however, that the central theme of "human capabilities" is too broad to accurately represent the range of research conducted by our associated investigators. There is a need to identify more precisely the specific practical area or areas of science to which our research is applicable. Partly as a result of consultation with a visiting scientist, Dr. Gilbert Ricard from Grumman Aircraft Corporation, we have elected to limit the future research focus to the subject of Human-Computer Interaction (HCI).

This change will probably be reflected in a new name for the Institute, as well as some shift in its group of associated investigators. Among the new areas of research emphasis will be computer visualization, voice-control of computer systems, and human-capability-based limits on HCI. Obviously, much of our previous research emphasis on cognition and decision-making, sensory processing and decision-making, and perceptual automaticity are directly relevant to HCI. Indiana University has three well-established research groups that will have the stronger ties with the reorganized Institute, the Department of Computer Sciences, the Instructional Systems Technology Program, and the Center for Innovative Computer Applications. Because of this reorganization, we

decided not to hold a fourth conference on Human Error, but instead to organize a satellite meeting at a national meeting on cognitive sciences, on the topic of HCI.

One of the major goals of the Institute has been to appoint a Visiting Investigator in Human Factors to augment our basic-science oriented research staff. During six weeks in the spring semester of 1993 (mid-April through May), Dr. Gilbert Ricard served in this capacity. Dr. Ricard devoted most of his time to an assessment of national needs in the field of human factors, with special emphasis on the HCI-related research program at Indiana University. A brief summary of his review paper is included.

The Institute, by these means, has provided partial support of research leading to the publication, during the past year, of 49 journal articles and book chapters, and the presentation of 20 papers at meetings of scientific societies.

Personnel

Investigators

Charles S. Watson, Ph.D., Director	Professor, Speech & Hearing Sciences Professor (part-time), Psychology
Richard M. Shiffrin, Ph.D., Associate Director	Waterman Professor, Psychology and Cognitive Science
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James C. Craig, Ph.D.	Professor, Psychology
S. Lee Guth, Ph.D.	Professor, Psychology and Visual Sciences
David B. Pisoni, Ph.D.	Professor, Psychology and Cognitive Science
Robert Port, Ph.D.	Associate Professor, Linguistics, Computer Science, and Cognitive Science
Donald E. Robinson, Ph.D.	Professor, Psychology and Adjunct Professor, Speech & Hearing Sciences
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James T. Townsend, Ph.D.	Rudy Professor, Psychology and Cognitive Science

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Gary R. Kidd, Ph.D.	Associate Scientist, Speech & Hearing Sciences
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Roderick Suthers, Ph.D.	Professor, Medical Sciences

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Visiting Scientist

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The following personnel contributed to research projects described in this report. Those entirely or partially supported by the Institute are identified by asterisks.

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Carol Cokely	M.A.	Audiology
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Martha Rinker	B.S.	Tactile Perception
Catherine L. Rogers	B.A.	Linguistics
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Carol Rhodes	B.A.	Institute for the Study of Human Capabilities

Introduction

This Annual Technical Report of AFOSR grant #90-0215, which funds the Institute for the Study of Human Capabilities, describes work in several areas, all of which focus on problems of skilled human performance. The Institute's investigators are primarily active in the fields of human cognition and decision making, and in sensory processes including vision, audition, and touch; research in those areas represent the major content of this report.

Specific projects continue to focus on human subjects' abilities to use information obtained from visual, auditory, and tactile displays. Both empirical and theoretical studies continue to be conducted. Studies of human cognition include a new theory of the limits of human auditory signal detection, the discovery of a common source of variance in auditory and visual speech perception (lipreading), automatization of perceptual processes, and automatization as a mechanism for overcoming attentional limitations.

Research Support. The research projects described in this report have been supported either partially or completely by the URI/AFOSR grant to the Institute for the Study of Human Capabilities. It is emphasized, however, that the majority of the investigators also receive project support from other agencies, as listed on pages 36 to 38 of this report. Institute funding, while a small portion of the total research support of the 13 affiliated laboratories, is a primary reason for the interdisciplinary cooperation that has developed among its affiliated scientists, during the past seven years. Institute funds have been used, roughly in order of amounts expended to:

(a) support graduate-student research assistants working on Institute-proposed projects;

(b) provide supplementary technical assistance for equipment design, maintenance, and computer program development;

(c) maintain and enhance apparatus for research in auditory signal detection;

(d) support short- and long-term visits to the Institute by scientists interested in application of basic research to human engineering problems;

(e) support a one-half time secretary-administrator, and one-third summer salary for the Institute Director; and

(f) support travel to scientific meetings for the purpose of reporting Institute-supported research.

Areas of Research. Current research projects in Institute-affiliated laboratories include studies in the following categories:

I. Auditory Discrimination: the psychophysics of auditory capabilities, the limits of auditory attentional capacity, the ability to discriminate signals composed of gaussian noise samples.

II. Multi-Modality Testing: comparison of individual differences in speech processing by ear and by eye.

III. Tactile Discrimination: development of tactile arrays, and studies of interference in tactile localization.

IV. Visual Discrimination: human peripheral vision, human visual optics, spatial processing of color information, perception of moving objects, and color theory.

V. Cognition and Decision Making: multi-stage decision making, perception of multidimensional complex sounds, differences between visual and memory search, connectionist models for auditory and speech perception, use of fault trees, and computer-based instruction.

VI. Connectionist Models of Sensory and Cognitive Processes: development and testing of neural networks for identification and discrimination of tonal sequences.

VII. New research in the Speech Research Laboratory: speech analysis, synthesis and perception, including word recognition and lexical access.

Form and Content of the Reports. It is not our intention to provide sufficient information in the brief project descriptions included here so that any of this work could be replicated. We believe such detail is best reserved for the descriptions of the work that will be submitted to appropriate journals, and specifically discourage any citation of reports which, like these, have not been through the scrutiny of independent peer review. We do hope, however, that the early knowledge of research that is underway or that, because of publication lags, will not appear for some time in the open literature, may be of value to colleagues who are working in closely related areas. We encourage readers of these brief reports to write to individual investigators if further detail is desired on any of the projects. In some instances draft manuscripts or technical reports are available, and we will do our best to provide whatever information is requested.

New Projects and Personnel. New projects have been begun during the past year in most of the Institute-affiliated laboratories, as described in later sections of this report. Richard Shiffrin has served as Associate Director of the Institute during this past year and his cooperation has been especially valuable because he also serves as Director of the University's Cognitive Science program. It seems clear that the applied field of human factors, if it is to move ahead with the rest of the scientific community, will need to adapt to (and benefit from) the "cognitive revolution."

Reprints. The bibliography at the end of this report lists articles by members of our research groups that have appeared over the past four years.

The design, conduct, and interpretation of experiments in these reports typically reflects the joint intellectual efforts of investigators, research assistants, and many others who participate in the research projects. While we try to give credit where it is due, the ownership of initial ideas is often impossible to establish. We are only certain of who does the work involved in the collection and analyses of data, and who writes the final papers; those persons are formally recognized through

authorship, but often a "group as a whole" is as close as one can come to the source of the original ideas for an experiment or for forms of analysis or, most importantly, for a theory. It is a pleasure, at any rate, to work with colleagues who seem to have an inexhaustible reserve of new ways to think about interesting problems.

CSW

I. Auditory Discrimination

The proportion-of-the-total-duration (PTD) rule holds for duration discrimination.
Gary R. Kidd, Charles S. Watson

In previous work, we demonstrated that frequency resolving power for each individual component of an unfamiliar sequence of tones increases with the component's proportion of the total sequence duration (Kidd & Watson, 1992). This work has now been extended to the case of duration discrimination. In this case, the dimension affected by changes in PTD (i.e., time) is also the primary dimension of variation within the patterns, as well as the dimension to which listeners must attend to perform the task. Listeners were asked to detect a change in the duration of a single tone in a five-tone pattern using a modified two-alternative forced choice procedure. Target-tone durations were determined by the PTD value (0.1, 0.2, or 0.4) and the total pattern duration (250 msec or 750 msec). Context-tone durations were determined randomly on each trial. A single frequency pattern, consisting of a sequence of ascending frequencies, was used throughout the experiment. The pattern of results obtained was essentially the same as that found in the frequency-discrimination experiments. Increases in the proportion of the total pattern duration occupied by the target tone consistently resulted in lower duration-discrimination thresholds.

Temporally directed attention in the detection and discrimination of auditory pattern components.
Gary R. Kidd

Thresholds for detection and frequency discrimination were determined for tones that occurred at unexpected temporal locations within twelve-tone sequences. Expectancies were established by repeated presentations of a standard pattern on each trial. Temporal deviations were introduced in comparison patterns by advancing or delaying the onset of a single "target" tone while maintaining the rhythmic structure of the surrounding context. Rhythmic patterns consisting of 350-ms and 150-ms intertone intervals were used to allow for a large range of temporal displacements. Thresholds were determined for target tones that were advanced ("early" targets) or delayed ("late" targets) by various degrees. Thresholds for displaced targets were elevated with respect to nondisplaced targets for both detection and discrimination. However, for most listeners, there was little or no effect of temporal displacement on detection except when targets were advanced by 200 ms or more. Temporal deviations had larger and more consistent effects on frequency discrimination for both early and late targets. The results are consistent with the view that, when presented with an auditory pattern, a listener's attention is dynamically allocated in time in response to the temporal structure of the pattern.

Use of the psychophysical method of adjustment in tonal pattern discrimination.
Charles S. Watson, Gary R. Kidd, Aimee Surprenant, Ward R. Drennan

A difficulty in tonal-pattern research is that several thousand trials are typically required to approach asymptotic discrimination performance under minimal-uncertainty testing conditions. One solution to this problem is to use the method of adjustment to determine thresholds, rather than a

forced-choice psychophysical method. In this study the extremely brief times that are required for a listener to achieve perceptual isolation for single components of a multi-tone patterns using the method of adjustment instead of a forced-choice method (minutes as opposed to hours) are demonstrated. A quantitative criterion for "perceptual isolation" is reached when a frequency match is made that is as close to the standard as can be achieved when the standard and variable tones are both presen' d in isolation, rather than in pattern contexts. Not all adjustments are this accurate, however. ıe most useful distinction between difficult and easy adjustments is shown to be the percent ◦ all the adjustments, for a given combination of target and context tones, that meet this perceptual-isolation criterion.

Properties of the structure of multi-tone sequential patterns that determine the difficulty of perceptually isolating single target components.
Charles S. Watson, Gary R. Kidd, Aimee Surprenant, Ward R. Drennan

A method of adjustment was used to establish the importance of each of several structural properties of the context tones, in nine-tone sequences, in determining the perceptual isolability of target components. Successful "perceptual isolation" of a target tone was assumed to be achieved when frequency matches were as accurate as those achieved for tones presented in isolation, generally meaning values of $\Delta f/f$ less than 1%--2% for the 50-ms tones in these sequences. The context property that was found to primarily affect the frequency matches was the separation, in Hz, between the target tone and both the local and (to a lesser degree) the remote context tones. Other than its bandwidth, the form of the local pitch contour (the target tone plus the single tones immediately before and after it) had no clear effect on the ability to "hear out" the target tone, i.e., whether the local context was ascending, descending, concave up, or concave down. The contours of the remote context tones (first and last three in the patterns) likewise had no effect on performance. Performance ranged from 25% target tones isolated for the most difficult conditions to 90% for the easiest.

The effects of training method on frequency discrimination for individual components of complex tonal patterns.
Robert F. Port, Catherine L. Rogers, Charles S. Watson, Gary R. Kidd

It has been assumed that subjects trained to detect increments in the frequency of all components of complex tonal patterns (broad focus) would be less accurate in detecting changes in a single target tone than subjects who have been trained to detect changes in only that component [e.g., Watson et al., *J. Acoust. Soc. Am.* **60**, 1176--1186 (1976)]. In several experiments, using a number of 750-ms ten-tone patterns, subjects were trained using one of three methods: in the first two, a S/2AFC procedure was used to train subjects to detect frequency increments in a specific target tone (group one) or to detect frequency increments that could occur in any of the ten components (group two), and in the third, subjects were trained only to identify the individual patterns. Subjects trained using these methods were tested on their ability to detect changes in various components of the patterns, including the target tone for the first group. In all of these experiments, only very slight differences in performance were found among the different groups. These results suggest that lengthy experience with a given pattern allows a listener to discriminate small differences in frequency in any of the individual components of that pattern, relatively independent of the nature of that experience.

Manuscripts and abstracts

Kidd, G. R., & Watson, C. S. (1992). The "proportion-of-the-total-duration (PTD) rule" for the discrimination of auditory patterns. *Journal of the Acoustical Society of America*, **92**, 3109-3118.

Kidd, G. R., & Watson, C. S. (1992). The proportion of the total-duration (PTD) rule holds for duration discrimination. *J. Acoust. Soc. Am.*, **92**, Pt. 2, 2318.

Kidd, G. R. (1993). Temporally directed attention in the detection and discrimination of auditory pattern components. *J. Acoust. Soc. Am.*, **93**, Pt. 2, 2315.

Watson, C. S., Kidd, G. R., Surprenant, A., & Drennan, W. R. (1993). Use of the psychophysical method of adjustment in tonal pattern discrimination. *J. Acoust. Soc. Am.*, **93**, Pt. 2, 2315.

Watson, C. S., Kidd, G. R., Surprenant, A., & Drennan, W. R. (1993). Properties of the structure of multi-tone sequential patterns that determine the difficulty of perceptually isolating single target components. *J. Acoust. Soc. Am.*, **93**, Pt. 2, 2315.

Port, R. F., Rogers, C. L., Watson, C. S., & Kidd, G. R. (1993). The effects of training method on frequency discrimination for individual components of complex tonal patterns. *J. Acoust. Soc. Am.*, **93**, Pt. 2, 2315.

Psychophysics of vowels

Effects of levels of stimulus uncertainty on discrimination of vowels
Kewley-Port

A series of experiments has examined the *discrimination of vowel formants* in a variety of phonetic contexts. In the first experiment, thresholds for F1 and F2 formant-frequency discrimination were obtained for ten synthetic, steady-state English vowels (Kewley-Port, 1990a; Kewley-Port and Watson, 1993). Thresholds were estimated, under minimal stimulus uncertainty, for both increments and decrements in either F1 and F2 formant frequencies. Reliable measurements of thresholds were obtained for most formants tested except when a harmonic of the fundamental fell at the center frequency of the formant. Excluding those cases, thresholds of ΔF as a function of formant frequency are best described as a piecewise-linear function which is constant at 14 Hz in the F1 frequency region (< 800 Hz), and increases linearly in the F2 region as shown in Fig. 1. In the F2 region, the resolution as $\Delta F/F$ is about 1.5%. The thresholds are similar to the most accurate formant discrimination previously reported in the F1 region, but about a factor of three lower in the F2 region.

Another series of minimal-uncertainty experiments obtained thresholds for one vowel, /I/, in a variety of consonantal contexts, /b, d, g, z, m, l/ (Kewley-Port & Watson, 1991). For F1 and F2, the resulting thresholds were a factor of 4-5 smaller than those reported in Mermelstein (1978) (who tested under medium levels of stimulus uncertainty). Relative to the isolated vowels, the thresholds for F1 did not generally change in consonantal context (although ΔF for /mIm/ and /lIl/ were larger by about 25%). Thresholds for F2 showed no significant change for /I/ in /bIb/, /dId/, and /zIz/, but for

a few f\subjects, a two-to-three-fold increase in ΔF threshold was obtained for /glg/, /mlm/, and /lll/. Additional experiments have estimated formant-frequency discrimination thresholds under *medium levels of stimulus uncertainty* (Kewley-Port, 1992). While longer training was required to approach asymptote, final thresholds were generally similar to those obtained for isolated vowels. Apparently, auditory acuity for formant frequency discrimination in well-trained subjects is generally the same for vowels in isolation and in CVC contexts, under both minimal and medium levels of stimulus uncertainty. Although the result that listeners perform similarly across those experimental conditions is not unexpected, given the life-long experience of the listener with the perception of "natural" vowels, the discrimination capabilities of the auditory system for vowels much better than expected.

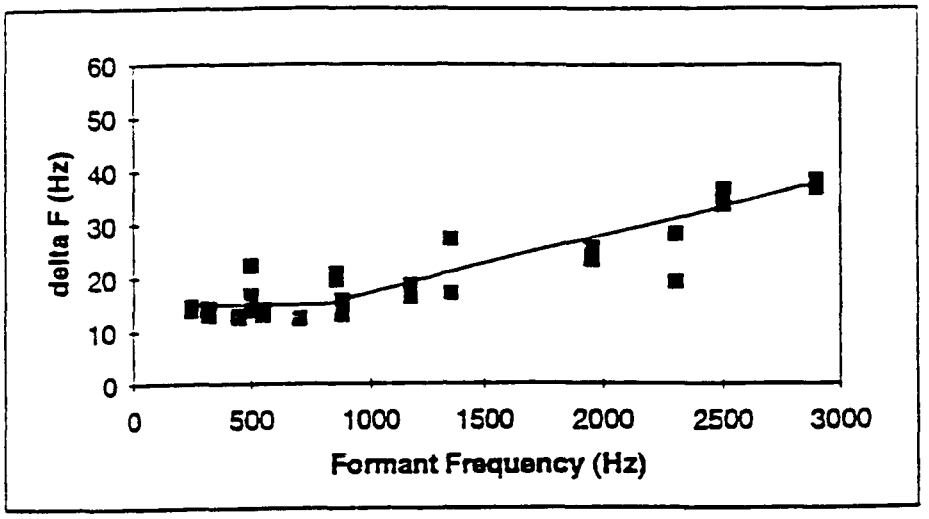

Figure 1. Thresholds for formant-frequency discrimination as a function of the frequency of F1 or F2 for female vowels from Kewley-Port and Watson (1993). A piece-wise linear regression function fits to the data as shown.

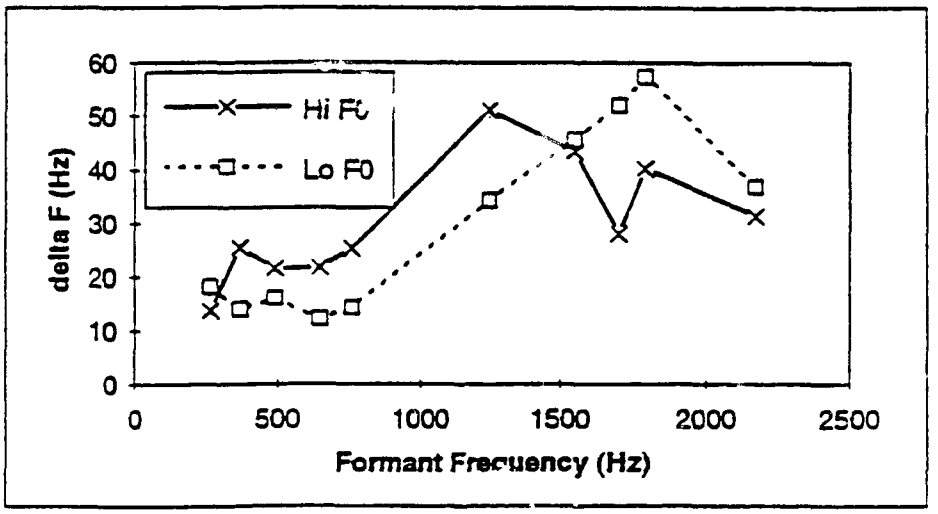

Figure 2. Thresholds for formant-frequency discrimination as a function of the frequency of F1 or F2 for male vowels from a pilot study. Thresholds for F0=126Hz are shown as crosses, and for F0=101Hz are shown as open squares.

Discriminability of noise samples
Robinson, Hanna, Fallon

Consider a two-interval same-different task in which listeners are asked to discriminate between trials on which a sample of noise is presented twice and trials on which two different samples are presented. Previous research has used this method to determine the effects of a wide range of stimulus conditions including temporal location of an uncorrelated segment, duration, bandwidth, correlation, and overall level [T. E. Hanna, *Percept. Psychophys*, **36**, 409-416 (1984); Fallon, S. M. and Robinson, D. E. *J. Acoust. Soc. Am.*, **78**, S46, 1985; Fallon, S. M. and Robinson, D. E. *J. Acoust. Soc. Am.*, **81**, S33, 1987; S. F. Fallon and D. E. Robinson, *J. Acoust. Soc. Am.*, **92**, 2630-2635 (1992)]. The data indicate that discriminability is best when changes occur at the end of the sample and that the ratio of the duration of the target segment to the total duration is independent of overall duration.

During the last year, we have concentrated on developing a mathematical model of the discriminability of complex auditory patterns. The model, which we reported at the Spring 1993 meeting of The Acoustical Society of America, is based on Jeffress' leaky integrator [L. A. Jeffress, *J. Acoust. Soc. Am.*, **44**, 187-203 (1968)]. In our model, the envelopes of the waveforms from the two intervals of the same-different task are extracted by a leaky integrator. Next, the envelopes are jittered in amplitude. Finally, the envelope from the second interval is subtracted from the envelope of the first interval. The RMS of the differenced envelopes becomes the predictor variable. The leaky integrator imposes a temporal weighting function,1 - Exp[-B t], such that the envelope of the noise waveform increases slowly after the onset of the integration process. The time constant of the integrator, B, and the variance of the amplitude jitter are the two free parameters of the model.

The model provides an excellent fit to the data reported by Fallon and Robinson. It provides quantitative predictions of the improvement in performance as the target (uncorrelated) noise segment is moved from the beginning to the end of the burst and predicts the constant ratio of the duration of the target segment to the total duration.

Multi-stage decision making
Sorkin, Robinson

This work began several years ago in collaboration with Professor Robert D. Sorkin. That research led to the development of two models of combined person-person or person-machine detection systems. The first model describes a system referred to as an alerted monitoring (AM) system. An AM system is one in which a first detector alerts a second one to the possibility of a signal on a channel which is also monitored by the second detector. The second detector then makes an observation of the channel and, with knowledge of the decision made by the first stage detector, makes the final decision. Examples of AM systems are found in many applied situations, e. g. medical diagnosis, nuclear power plant control rooms, flight decks of commercial and military aircraft, etc. The AM model was developed using techniques from the Theory of Signal Detectability (TSD). The model suggests that AM systems can result in improved performance compared to a single-stage system. [Sorkin, R. D. and Woods, D. D. Systems with Human Monitors: A Signal Detection Analysis. *Human Computer Interaction*, 1984, **1**, 49-75. Sorkin, R. D. and Robinson, D. E. "Alerted-Monitors: Human Operators Aided by Automated Detectors", *DOT/OST/P-34/85/021*,

U.S. Dept. of Transportation, 1985.

The second model of two-stage decision making, an outgrowth of the first, involves a slightly different situation. In the AM system, the second stage (typically a human operator) only monitors a channel when alerted to by the first stage. Another situation is one in which the task of the human is to monitor a noisy channel on which information about a potentially dangerous condition may appear. An alarm system also monitors an independently noisy channel for information about the same threatening condition. Using basic concepts of statistical decision theory, the Contingent Criterion Model of such a person-machine system has been developed. According to the model, the human should establish two criteria for responding: one contingent on an alarm from the automated detector and one, on no-alarm. The model shows large gains in performance compared to either detector alone. [Robinson, D. E. and Sorkin, R. D. A Contingent Criterion Model of Computer Assisted Detection, In *Trends in Ergonomics / Human Factors*, vol. II, R. Eberts and C. G. Eberts (Eds.), North-Holland: Amsterdam, 75-82, 1985.]

In addition to continuing our work on decision theory-based models of combined person-machine detection systems, we have extended our work in this area to include recognition systems consisting of an autoclassifier and a human monitor. In these systems, a human operator monitors a noisy channel and attempts to detect and classify signals. The operator is aided by an automated device which also attempts to detect and classify the same signals on an uncorrelated noisy channel. Both the automated device and the operator are modeled as multi-channel detection-recognition devices. For each stage (autoclassifier and operator), it is assumed that if the observation in any one of m channels exceeds criterion, a response of "yes" is made. Then, the channel having the largest output is selected as the one containing the target. By combining the Contingent Criterion model described above with a model of simultaneous recognition and detection (Starr, S. J.,Metz, C. E., Lusted, L. B., and Goodenough, D. J., *Radiology*, **116**, 533-538, 1975), we have developed the Contingent Criterion Recognition (CCR) model. The model indicates that large gains in target identification may be achieved relative to either stage operating alone.

Robustness of psychophysical measures
Rickert, Robinson

Also in the last year we have completed the mathematical analysis of several well-known measure of psychophysical performance. In this work we were interested in the degree to which such measures as d', P(C), P(C)max, and A' are "robust" with respect to violations in their underlying assumptions. The basic approach was to investigate how each of these measures varies with changes in criterion placement for various pairs of assumed underlying density functions. The pairs of density functions investigated were normal-normal, exponential-exponential, Chi Square-Noncentral Chi Square, and Rayleigh-Rice.

Our findings indicate that measures which rely on the assumption of equal-variance, normal densities, such as d' and P(C)max, are quite robust, particularly if extreme values of the criterion are avoided, e.g. changes in the criterion have small effects except for very low or very high false alarm rates. The so-called non-parametric measure, A', is not robust, and, in fact, shows large changes in magnitude as the criterion is varied on any of the density pairs we investigated.

Manuscripts and abstracts

Fallon, S. F. and Robinson, D. E. (1992). Discriminability of reproducible bursts of noise. *J. Acoust. Soc. Am.*, **92**, 2630-2635.

Rickert, M. R. and Robinson, D. E. (1993). A Stimulus-Oriented Model for the Discrimination of Gaussian Noise Samples. *J. Acoust. Soc. Am.*, **93**, 4, Pt. 2, 2386.

II. Multi-Modality Testing

Correlations between auditory and visual speech processing ability: evidence for an modality-independent source of variance.
Watson, Qiu, Chamberlain, Li

Two experiments were run to determine whether the individual differences in auditory speech processing are predictable from those in speechreading, using a total of 90 normal-hearing subjects. Tests included single words and sentences. The speech was recorded on a video disk by a male actor (Bernstein and Eberhardt, 1986), Johns Hopkins Lipreading Corpus. The auditory speech was presented with a white noise masker, at -7 dB Sp/N. The correlations between overall auditory and visual performance were 0.52 and 0.45, in the two studies, suggesting the existence of a modality-independent ability to perceive linguistic "wholes" on the basis of linguistic fragments. Subjects also identified printed sentences with 40-60% of the portions of the letters deleted. Performance on the "visual-fragments" test also correlated significantly with visual and auditory speech processing.

A manuscript describing this work has been completed and will be submitted to *J. Acoust. Soc. Am.*

III. Tactile Discrimination

Tactile attention.
Evans, Craig, Rinker

We are conducting a series of studies to examine how well subjects can attend to one site of stimulation on the skin, a target site, and ignore stimulation at some other site on the skin, a nontarget site. The stimuli are patterns moving across the fingerpads in particular directions. The subject's task is to attend to a particular fingerpad and identify the direction of movement at that pad. Previous results have shown that presenting a nontarget pattern at another fingerpad interferes with the perception of the target stimulus.

Using this paradigm, we have begun two new types of studies. In the first we investigated the effect of spatial orientation on this interference effect. Interference is only seen when the target and nontarget are moving in different directions. When the two stimuli are moving in the same direction, whether the subject responds with the target or with the nontarget, they will be correct. In all the previous studies the two tactile displays were placed horizontally side by side in front of the subject. In the new studies, the displays were rotated 90 degrees and placed back to back. The subject gripped the two displays between the index finger and thumb. This rotation of the two displays changes the relative motion across the displays. Suppose a pattern is presented to the left hand and moved from right to left on the thumb and a second pattern is moved from right to left on the index finger when the two displays are horizontal. When the displays are placed vertically, the direction would change such that the movement would be "up" on the thumb and "down" on the index finger. The question we asked was whether subjects would respond as though they perceived the "local" pattern of motion across the fingerpad or the "external" pattern of motion. Consistently subjects responded in the latter fashion as though they perceived a single object moving between the index finger and thumb.

The second type of study examined the temporal course of the interference effect. The interference effect has been observed with brief temporal separations between the target and nontarget. Specifically, when the nontarget preceded the target by 50 to 100 msec. Similar findings with visual stimuli have been interpreted to mean that the nontarget "primes" a conflicting response. Recently we have investigated in greater detail the temporal course of the effect and have found that with tactile stimuli there is greater interference when the nontarget follows the target by a brief interval. These measurements have been extended to include sites on the forearm as well. The findings suggest that interruption may play a bigger role in the processing of tactile stimuli than in the processing of visual stimuli.

Presentations:

Craig, J.C., & Rinker, M.A. Effect of hand position on perception of tactile stimuli. Presented to *Psychonomic Society*, November, 1992.

Evans, P.M., & Florl, L.K. The perception of target and nontarget stimuli presented to the forearm. Presented to *Psychonomic Society*, November, 1992.

Manuscripts and abstracts:

Evans, P.M., Craig, J.C.. & Rinker, M.A. (1992). Perceptual processing of adjacent and nonadjacent tactile nontargets. *Perception & Psychophysics*, **52**, 571-581.

IV. Visual Discrimination

A. Human Vision

Spatial Vision

Psychophysical determination of the factors limiting human peripheral vision.
Thibos, Bradley, Wang, Anderson

Gratings beyond the Nyquist limit of the peripheral retina are visible as aliased percepts when presented in isolation. However, recent experiments using complex stimuli (edges, lines, letters) suggest that aliased supra-Nyquist components (f2) may not be visible in the presence of sub-Nyquist gratings (f1). The purpose of our study was to test this hypothesis. Using a three-alternative forced-choice paradigm, subjects were required to discriminate a 2.5 deg patch of compound grating (f1 + f2; components oriented orthogonally) from a simple grating (f1 only). In a control condition, discrimination performance increased from chance level to 100% correct over the f2 contrast range 5%-20% and average threshold contrast (75% correct) for 4 subjects was 14.5%. In the test condition, discrimination performance dropped significantly at any particular value of f2 contrast. However, this performance loss could be recovered by increasing f2 contrast. Average threshold contrast for the f2 component increased to 21%, representing a 0.16 log-unit increase over the control condition. These results demonstrate that under the conditions or our experiments, aliased supra-Nyquist components are visible in the presence of high contrast, sub-Nyquist gratings. We conclude that the peripheral visual system is capable of using aliased frequency components of a complex stimulus for pattern discrimination.

Manuscripts and abstracts

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Wang, Y., Anderson, R.S., Thibos, L.N., and Bradley, A. (1993) Aliased frequencies enable the discrimination of compound gratings in peripheral vision. *Invest. Ophthal. Vis. Sci.* **34** (suppl.), 777.

Thibos, L.N. and Bradley, A. (1992) New Methodologies for discriminating neural and optical losses of vision. *Optometry and Vision Science* **70**, 279-287.

Bradley, A, Thibos, L.N., Wang, Y., Haggerty, K., and Poorman, A. (1992) Imaging FWC. *Opthalmic and Physiological Optics.* **12**, 18-23.

Anderson, R. A., Wilkinson, M. O. & Thibos, L. N. (1992). Psychophysical localization of the human visual streak. *Optom. Vis. Sci.*, **69**, 171-174.

Chromostereopsis.

Ye, M., Bradley, A., Zhang, X., Thibos, L.T. (1992) The effect of pupil size on chromostereopsis and chromatic diplopia: Interaction between the Stiles-Crawford effect and chromati aberrations. *Vision Research* , **32,** 2121-2128.

Color vision.

Bradley, A., Zhang, X.X. and Thibos, L.N.,(1992) Failures of isoluminance caused by ocular chromatic aberrations. *Applied Optics* **31,** 3657-3667..

Bradley, A. Zhang, X. X. and Thibos, L. N. (1992). Failures of isoluminance caused by ocular chromatic aberrations. *Applied Optics* (in press).

B. Human Factors and Applied (Clinical) Research

Manuscripts and abstracts

Entopic visualization of retinal vascular detail.

Bradley, A., Applegate, A., Zeffren, B., and van Heuven, W. (1992) Psychophysical measurement of the size and shape of the human avascular zone. *Ophthalmic and Physiological Optics,* **12,** 18-23.

Evaluation of clinical tests of contrast sensitivity.

Rahman, H.A., Bradley, A.. and Soni, S. and Zhang, X. (1992) Letter Contrast sensitivity with simultaneous vision bifocal contact lenses. *OptomVision Sci.* (in press).

Rynders, M.C. and Thibos, L.N. (1993) Single channel, sinusoidally modulated signal generator, with variable temporal contrast. *Optical Society of America Technical Digest (1992 Non-invasive Assessment of the Visual System Topical Meeting)* **1,** 194-197.

Ophthalmic Optics

Atchison, A.A., Ye, M., Bradley, A., Collins, M.J., Zhang, X., Thibos, L., and Rahman, A. (1992) Chromatic Aberration and Optical Power of a Diffraction Bifocal Contact Lens. *Optometry and Vision Science,* **69,** 797-804.

Thibos, L.N. and Bradley, A. (1992) Use of interferometric visual stimulators in optometry. *Ophthal. Physiol. Opt.* **12,** 206-208.

Applegate, R.A., Bradley, A, and Thibos, L.N. (1992) Visual Acuity and Pupil size in Maxwellian and free view systems with and without refractive error. *Optical Society of America Technical Digest (1992 Non-invasive Assessment of the Visual System Topical Meeting)* **1**, 170-174.

C. Human Visual Optics

A new schematic eye that accurately models human spherical and chromatic aberration.
Bradley, Ye, Zhang, Thibos

The optical system of the human eye represents a low-pass spatial filter at the front-end of the visual system that limits the spatial information available for vision. An accurate and computationally simple optical model of the human eye can provide a valuable tool in evaluating the relative contributions of neural and optical filters to human spatial vision. We have recently published a single surface model eye that accurately models ocular chromatic aberration. We now extended this model to reflect spherical aberrations of the eye.

Manuscripts and abstracts

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Ye, M., Zhang, X., Thibos, L.N., and Bradley, A. (1993). A new single-surface model eye that accurately predicts chromatic and spherical aberrations of the human eye. *Invest. Ophthal. Vis. Sci.* **34** (suppl.), 777.

Thibos, L.N. (1992) Application of Fourier analysis to the description of optical lens power and the statistical analysis of refractive error. *Optom. Vis. Sci.* **69** (suppl), 114.

Measurement of ocular chromatic aberration.

Zhang, X., Bradley, A., and Thibos, L.N. (1992) Experimental determination of the chromatic difference of magnification of the human eye and the location of the anterior nodal point. *OJ. pt Soc Am* **10**, 213-220.

Visual Optics

Thibos, L. N., Ye M, Zhang, X, and Bradley, A. (1991) The Chromatic Eye: A new reduced-eye model of Ocular Chromatic Aberration in humans. *Applied Optics* **31**, 3594-3600.

Zhang, X., Bradley, A., Ye, M. and Thibos, L. N. (1992) An experimental model of bifocal vision. *Optical Society of America Technical Digest (1992 Ophthalmic and Visual Optics Topical Meeting)* **3**, 102-105.

Bradley, A., Thibos, L.N., Wang, Y., Haggerty, K., and Poorman A. (1992) Imaging FWC. *Ophthalmic and Physiological Optics*, **12**, 128-9.

Optical correction of chromatic aberration.

Bradley, A. (1992) Glen Fry Award Lecture: Perceptual manifestations of imperfect optics in the human eye: Attempts to correct for Ocular Chromatic Aberration. *Optom. Vis. Sci.* (in press).

D. Event Perception

Visual perception of lifted weight.
Bingham

Observers viewing displays created by filming people lifting weights from 5 lb to 65 lb so that only bright patches attached to the major limb joints can be seen in the displays have been shown to be able to judge the amount of weight lifted. The natural question is how mere motions can provide visual information for amount of lifted weight. The original studies used standard displays in which observers where told the amount of weight lifted. We have replicated these studies without standard displays demonstrating that they are not required for the result. Further, we have varied the size of the lifters from 115 lb to 190 lb in displays containing no static information for lifter size (e.g. image size of patches or the distribution of patches) and varied the range of weights lifted by each lifter and shown that observers remain able to judge lifted weights. This implies that the motions provide information for lifter size. Current experiments are investigating this possibility.

Manuscripts and abstracts

Bingham, G.P. (1992). Scaling judgments of lifted weight: Lifter size and the role of the standard. *Ecological Psychology*, 5(1), 31-64.

Perceiving the size of objects in events

Presentations

Muchisky, M.M. & Bingham, G.P. (1992). Perceiving size in events via kinematic form. Presented at the *14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 31st.

Manuscripts and abstracts

Muchisky, M.M. & Bingham, G.P. (1992). Perceiving size in events via kinematic form. In I. Kruscke, (ed.) *Proceedings of the 14th Annual Conference of the Cognitive Science Society*, pp. 1002-1007. Hillsdale, N.J.: Erlbaum.

Visual perception of tree size.

Presentations

Bingham, G. P. (1992). Perceiving the size of trees via their form. *Presented at the 14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 30th.

Bingham, G.P. (1992). Form as information about scale: Perceiving the size of trees. Presented at a meeting of the Psychonomic Society, St. Louis, MO, November 13th.

Publications

Bingham, G. P. (1992). Perceiving the size of trees via their form. In J. Kruscke, (ed.) *Proceedings of the 14th Annual Conference of the Cognitive Science Society*, pp. 295-300. Hillsdale, N.J.: Erlbaum.

Bingham, G.P. (1992). Perceiving the size of trees : Form as information about scale. *Journal of Experimental Psychology: Human Perception and Performance.* (In press.)

Bingham, G.P. (1992). Perceiving the size of trees: Biological form and the horizon ratio. *Perception & Psychophysics.* (In press.)

Visual identification of events

Manuscripts and abstracts

Bingham, G.P. (1992). Dynamics and the problem of visual event recognition. To appear in Port, R. & T. van Gelder (eds.), *Mind as Motion: Dynamics, Behavior and Cognition.* Cambridge, MA: MIT Press.

Bingham, G.P., Rosenblum, L.D. & Schmidt, R.C. (1992). Dynamics and the orientation of kinematic forms in visual event recognition. Submitted to *Journal of Experimental Psychology: Human Perception and Performance.*

E. Perception/Action

Optic flow generated by eye movements.

Manuscripts and abstracts

Bingham, G.P. (1993). Optical flow from eye movement with head immobilized: "Ocular occlusion" beyond the nose. *Vision Research,* 33(5/6), 777-789.

Bingham, G.P. (1992). The implications of ocular occlusion. *Ecological Psychology.* (In press.)

Object shape as visual information about the center of mass.

Manuscripts and abstracts:

Bingham, G.P. & Muchisky, M.M. (1992). "Center of mass perception:" Affordances as dispositions determined by dynamics. To appear in Flach, J.M., P. Hancock, J. Caird & K. Vicente (eds.), *The Ecology of Human-Machine Systems*. Hillsdale, N.J.: Erlbaum.

Bingham, G.P. & Muchisky, M.M. (1992). Center of mass perception and inertial frames of reference. *Perception & Psychophysics*. (In press.)

Bingham, G.P. & Muchisky, M.M. (1992). Center of mass perception: Perturbation of symmetry. *Perception & Psychophysics*. (In press.)

Sensorimotor learning in reaching with vision through a displacement prism

Presentations:

Romack, J.L., Buss, R.A. & Bingham, G.P. (1992). "Adaptation" to displacement prisms is sensorimotor learning. Presented at the *14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 31st.

Bingham, G.P. & Romack, J.L. (1993). Targeted reaching with perturbation of visual direction. Presented at the *18th Annual Interdisciplinary Conference*, Jackson Hole, Wyoming, January 17-22.

Bingham, G.P. (1993). Spatio-temporal information in visually guided reaching. Presented at the conference sponsored by the *Office of Naval Research on Neural Representations of Temporal Patterns* at Duke University, Durham, North Carolina, May 1st.

Manuscripts and abstracts:

Romack, J.L., Buss, R.A. & Bingham, G.P. (1992). "Adaptation" to displacement prisms is sensorimotor learning. In J. Kruscke, (ed.) *Proceedings of the 14th Annual Conference of the Cognitive Science Society*, pp. 1080-1085. Hillsdale, N.J.: Erlbaum.

Bingham, G.P. & Romack, J.L. (1992). "Adaptation" to displacement prisms is skill acquisition: Analysis of movement times. Submitted to Journal of Experimental Psychology: *Human Perception and Performance.*

F. Color Vision

Theory and data concerning color perception and visual adaptation.
Guth

A model for color perception and visual adaptation has been developed by Dr. Guth with full support from the Institute. The model has been published as a major paper in the *Journal of the Optical Society of America*, and it represents an important advance in the visual sciences. That is, given the physical specification of a light, the model allows predictions of the light's detectability, brightness, hue and saturation. Also, the model will predict if the light will be discriminably different from other nearby lights of background fields, and it can make these predictions for vision under a very wide range of chromatic and achromatic adaptation conditions.

Recent work on the model has allowed it to make predictions over an increased range of luminance levels, and it is now presented in a form that makes it more accessible to lighting and imaging engineers for use in the applied sector.

A question that emerged from development of the model concerned whether or not the stimulus that appears as a perfect white (*i.e.*, completely achromatic) varies with intensity level. The two existing studies disagree. Experiments with Mr. T. Petersime (a graduate student) show that the perception of "unique" white is indeed invariant with intensity changes. (The model has been modified to reflect this fact.)

Manuscripts

Guth, S.L. (1993). Unified model for human color perception and visual adaptation II. *SPIE Proceedings, 1992* (in press).

Presentations

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V. Cognition and Decision Making

Attention, automatism, and skill learning.
Shiffrin

Nancy Lightfoot and I are continuing research on perceptual learning and automatic processing. Several articles and papers have appeared giving reports; we have constructed novel visual characters, and shown that these consist of three separate simple visual features. After extensive training, these features cohere into a single perceptual unit. We have shown what sort of training is required for this to occur, which features join the unit, and which do not, and what sort of generalization from the new unit takes place.

Nancy Lightfoot and I also are developing a model for visual search incorporating interitem similarity, based on careful scaling of the stimulus set (alphabetic characters), and elucidating the roles of attentive and automatic processing. This work is not yet published.

Michael Fragassi, Asher Cohen, David Diller, and I have been exploring the degree to which visual information is processed from one part of the visual field during the time period that attention is focused on another part of the visual field. One talk on this work was presented at last year's Psychonomic Society meetings. Some automatic processing appears to take place in such cases, though the effect is strongly gated by a superordinate non- specific attentive process.

Memory and learning.
Shiffrin

Peter Nobel and I are continuing research on response times in recall and recognition, using free response and signal-to-respond techniques. We have extensive data suggesting that different retrieval processes underlie recognition and cued recall behavior, and are now developing models for the results.

Larissa Samuelson and I have examined the role of context cuing in recognition, finding dramatic differences when retrieval is directed toward older as opposed to recent memories. This work is being prepared for publication.

Dave Huber, Kim Marinelli, and I have used a category task to examine how familiarity changes when list length, strength, and list strength are varied. Familiarity rises with length and strength, but not with list strength. This is consistent with the predictions of the SAM model, but no other extant models. This work is being prepared for publication.

Dave Huber and I have examined an alternative model for the list- strength findings, based on inhibitory processes operating during dynamic retrieval. This research was reported at the mathematical psychology meetings, and is being prepared for publication.

Manuscripts and abstracts

Shiffrin, R.J., & Raaijmakers, J.G. (1992). The sam retrieval model: A retrospective and prospective. In Healy, A., Kosslyn, S., & Shiffrin, R.M. (Eds.), *From Learning Processes to Cognitive Processes: Essays in Honor of William K. Estes*, Volume 2, pp. 69-86. Hillsdale, NJ: Erlbaum.

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Shiffrin, R.M., Czerwinski, M.P., & Lightfoot, N. (in press). On the automatization of visual search. In Izawa, C. (Ed.), *Cognitive Psychology Applied*. Hillsdale, NJ: Erlbaum.

Clark, S., & Shiffrin, R.M. (1992). Automatization and training in visual search. *American Journal of Psychology*, Vol. 105, **22**, 271-315.

Huber, D.E., Zeimer, H.E., & Shiffrin, R.M. (1992). Does memory activation grow with list strength and/or length? *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society*, pp. 277-282. Hillsdale, NJ: Erlbaum.

Nobel, P.A. & Shiffrin, R.M. (1992). Constraints on models of recognition and recall imposed by data on the time course of retrieval. *Proceeding of the Fourteenth Annual Conference of the Cognitive Science Society*, pp. 1014-1019. Hillsdale, NJ: Erlbaum.

Dynamic field theory of decision making.

Manuscripts and abstracts

Busemeyer, J., & Townsend, J. R. Decision field theory: A dynamic-cognitive approach to decision making. In press. *Psychological Review.*

Townsend, J. T. (1992). Don't be fazed by PHASER: Beginning exploration of acyclical motivational system. *Behavior Research Methods, Instruments and Computers* , **24**, 219-227.

Presentations

Townsend, J. T., Invited Address by Jerome R. Busemeyer of Purdue University: A decision Field Theory Account of Some "Paradoxical" Findings from Decision Research.

Townsend, J. T., Invited Presentation at IU Institute for the Study of Human Capabilities, Conference on Human Error: A New Theory of Ordinal Decision Making in Statistical Inference. March 22, 1991; Bloomington, IN.

General recognition theory: parallel vs. serial processing.

Manuscripts and abstracts

Kadlec, H., & Townsend, J. T. (1992). Implications of marginal and conditional detection parameters for the separabilities and independence of perceptual dimensions. *Journal of Mathematical Psychology*, **36**, 325-374.

Townsend, J. T., & Thomas, R. Stochastic dependencies in parallel and serial models: Effects on systems factorial interactions. In press. *Journal of Mathematical Psychology*.

Presentations

Van Zandt, T., & Townsend, J. T. Self-terminating vs exhaustive processes in rapid visual and memory search: An evaluative review. In press. *Perception & Psychophysics*.

Nozawa & Townsend, J. T. (August, 1991). Analyses of reaction times obtained in the redundant target paradigm: Evidence for parallel processing. Twenty-fourth Annual Meeting of Society for Mathematical Psychology, Bloomington, IN.

Thomas, R., & Townsend, J. T. (1990, August). Stochastic dependencies in parallel and serial models: Effects on systems factorial interactions. Paper presented at *Twenty-third Annual Meeting of Society for Mathematical Psychology*, Toronto, Montreal.

Kadlec, H., & Townsend, J. T. (1990, August). Testing separabilities and independence with signal detection analyses. Paper presented at *Twenty-third Annual Meeting of Society for Mathematical Psychology*, Toronto, Montreal.

Decision-making models

Manuscripts and abstracts

Castellan, N. J., Jr. (1993). Paradoxes in individual and group decision making: A plea for models. In. N. J. Castellan, (Ed.)., *Individual and Group Decision Making: Current Issues*. Hillsdale, NJ: L. Erlbaum. Pp. 125-134.

Castellan, N. J., Jr. (1993). Evaluating information technology in teaching and learning. *Behavior Research Methods, Instruments, & Computers*, **25**, 233-237.

Castellan, N. J., Jr., (Ed.). (1993). *Individual and Group Decision Making: Current Issues*. Hillsdale, NJ: L. Erlbaum.

VI. Connectionist Models of Sensory and Cognitive Processes

A connectionist approach to the acquisition of morphophonemic rules.
Gasser

Work during the past year has focused on modeling the learning of the ability to recognize polymorphemic words formed with a variety of morphological rules. It has been shown that separate network hidden layers responsible for root recognition and inflection recognition improves performance dramatically. This provides a new argument for the division between lexicon and grammar which is a part of conventional models of language processing and acquisition.

Modeling the development of the concept of sameness.
Gasser, Smith

Recent work with our network model of lexical learning has focused on isolating factors which lead to the advantage of nouns over adjectives in early lexical learning. Categories which encompass relatively large and compact regions in representational space are learned faster, categories which are elicited with questions about dimensions ("what color is it?") are learned more slowly than those which are not ("what is it?"), and types of categories for which there are more members to be learned are learned more slowly. The first three of these factors favor nouns, the last adjectives. Our experiments show that accounts of the noun advantage do not require prior knowledge of the noun-adjective distinction.

Manuscripts and abstracts

Gasser, M. (1992). Phonology as a byproduct of learning to recognize and produce words: A connectionist model. *Proceedings of the Second International Conference on Spoken Language Processing*, 277-280.

Accepted

Gasser, M. (1993). The structure grounding problem. *Fifteenth Annual Conference of the Cognitive Science Society.*

Presentations

Gasser, M. (March, 1993) A neural network model of developmental changes in naming behavior (with Linda B. Smith). *60th Meeting of the Society for Research in Child Development*, New Orleans.

Gasser, M. (December, 1992) Grounding structure. Presentation, Workshop on Approaches to Symbol Grounding, *Neural Information Processing Systems Post-Conference Workshops*, Vail, CO.

Gasser, M. (October, 1992) Why are nominal terms learned faster than dimensional adjectives? (with Linda B. Smith). *17th Annual Boston University Conference on Language Development*, Boston.

Dynamic short-term auditory memory by connectionist models
Robert Port, Devin McAuley, Sven Anderson, Joseph Stampfli
Department of Linguistics, Department of Computer Science, Department of Mathematics

We are building functional models that can directly process auditory information in time. We employ recurrent networks, that is, networks with many recurrent or feedback connections. This portion of the overall project attempts to construct a memory that simulates human 'sensory trace memory' for auditory intensities in various frequency ranges. It is an extension of the model proposed by Zipser (1991). The model stores the intensity of an input tone for a period of time and gradually decays ('forgets') the tone intensity. The resulting sensitivity of the model to stimulus-onset asynchrony for a roving intensity discrimination task has been demonstrated for human listeners on a similar task (Berliner and Durlach, 1973). We have studied the dynamic behavior of this model under varying conditions of internal noise and have undertaken mathematical analysis of the model as well. A surprising discovery is that under certain conditions the presence of noise actually improves the performance of the memory. Our research has explored the nature of those conditions.

Manuscripts and abstracts

McAuley, J. Devin, Sven Anderson and Robert F. Port (1992) Sensory discrimination in a short-term trace memory. In *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society.* (L. Erlbaum, Hillsdale, NJ), pp. 136-140.

McAuley, J. Devin, Joseph Stampfli and J. A. Holt (1993) The Role of Noise in Trace Memory. In Penna, M., S. Chittajallu and P. Madhavan, *IUPUI Machine Intelligence Research Group,* Indianapolis, Indiana, pp. 259-266.

Temporal pattern recognition with networks
Sven Anderson, Devin McAuley, Robert Port, Fred Cummins and Joseph Stampfli

A number of additional simulations were conducted during this year plus the development of Anderson's dissertation project. The stimuli were simulated tone sequences presented as 8-step patterns as though the FFT frames of sinusoids -- thus in connectionist terms, they were orthogonal input vectors, in some cases with significant amounts of added noise. In one simulation, our fully recurrent network was fed randomly ordered measures in a stream and trained to recognize occurrences of the two target measures. Even with a signal/noise ratio (per individual frame) of 0 dB, the system could distinguish two target sequences from the nine other competing sequences with d' larger than 2.0. This is good performance and suggests that, despite the limitation of being unconstrained in architecture, this approach may be useful as a model of rate-invariant and noise-resistant pattern recognition. Dynamic memory allows the input pattern itself to entrain the response of the network. Apparently this system is robust enough to handle considerable natural variation in inputs. This is a step toward a continuously functioning dynamically controlled perceptual system for auditory patterns. In Anderson's dissertation work, he has developed more constrained architectures that self-organize to recognize common acoustic sequences in the sounds presented to the model. Employing Grossberg-like shunting equations in cliques of inhibitory clusters, the model can learn sound patterns of apparently arbitrary complexity.

Manuscripts and abstracts

Anderson, Sven E. (1993) Unsupervised development of sequence-selective units in an artificial neural network. In *Computational Neuroscience Symposium*, 1992. Ed by M. Penna, S. Chittajallu and P. Madhavan (IUPUI Machine Intelligence Research Group, Indianapolis, Indiana), pp. 267-274.

Anderson, Sven E. (1992) Self-organization of auditory motion detectors. *Proceedings of the 14th Annual Conference of the Cognitive Science Society* (L. Erlbaum) pp. 684-689.

Recognition of rhythmic patterns
J. Devin McAuley, Robert Port, Michael Gasser

Rhythmic patterns present another important subclass of sounds for analysis. Proper response of a model show be the ability to recognize a rhythmic pattern despite changes in rate and the ability to predict when subsequent events from the pattern will occur. Developments this year include a system that quickly 'learns' to respond at the correct rate when stimulated with pulses at a regular periodicity. This project will become J. D. McAuley's thesis project. Other simulations using a fully recurrent network demonstrate that in simply learning a sequence, the model will discover if patterns have any periodicities in them. If they do, these periodicities will be exploited by the model to differentiate targets from nontargets.

Listening experiments with tone sequences
Kidd, Rogers, Port, Watson, Anderson, McAuley

This year we conducted 2 experiments on minimal or low uncertainty tone-sequence perception. The experiments are extensions of the Spiegel and Watson (1981) experiments using tone patterns that are very familiar. Subjects are given considerable training on a single tone pattern at a time and asked to discriminate changes in one tone in each pattern. After training one tone in a pattern, we probed subjects' ability to resolve changes in both the target tone and other tones in the pattern. Our results show that when listeners know a pattern well, they are just about as good at detecting changes in non-target tones as in the target tone -- no matter whether they were trained for a particular target, for multiple target tones or simply for identification of the pattern as a whole.

Manuscript

Port, Robert, Catherine Rogers , Charles Watson and Gary R. Kidd (1993) The effects of training method on frequency discrimination of individual components of complex tonal patterns. *J. Acous. Soc. Amer.* Presented at Spring Meeting (Ottowa) of ASA.

Temporal microstructure in speech perception
by R. Port, Juan Pablo Mora, Catharina de Jonge, Sven Anderson

Many experiments on lexical minimal pairs have demonstrated the role of timing in the identification of words. Other work on less well controlled contexts suggests that temporal

information may not be very useful for ordinary perception due to the large degree of variation from uncontrollable contextual features. We have two subprojects for which primary data collection was done in previous years but manuscript development has continued.

First, in a series of experiments using simplified speech-like non-speech stimuli whose temporal structure is based upon natural utterances, we have demonstrated that native speakers can identify words much better than nonnative listeners. Furthermore, we found to our initial surprise that a simple linear discriminant function using the vector of segment durations for a set of 30 tokens each of 3 English words was able to identify the words far better (88% correct) than native listeners (58% correct) as well as a group of Spanish speakers who speak English with a foreign accent (43% correct). There are two places to look for an explanation of this effect. The less likely possibility is that the human listeners found it impossible to optimize the combination of the durational measurements from each token. The more likely explanation, in our view, is that the human listeners are unable to simply measure the durations of the segmental intervals in these stimuli very well.

Second, Anderson and Port explored the possibility of exploiting temporal detail to directly identify suprasegmental features of words and phrases from the temporal properties of measurable segmental units.

Manuscript

Mora, Juan Pablo, Robert F. Port and Catharina de Jonge (1991) Cross-language word identification using durational cues only. Paper presented at the Acoustical Society of America. *Journal of the Acoustical Society of America* **90**, (A) 2253.

Models for general and temporal human cognition
R. Port and T. van Gelder

An important idea seems to have emerged independently in many areas of cognitive research. This is the use of dynamic models for the representation of cognitive objects. Dynamic models have been proposed for such diverse cognitive phenomena as perceptual differentiation of scents, motor control of the limbs, linguistic control of the articulatory apparatus in speech, developmental 'stages' in cognition, etc. But these models are so different as to be almost incommensurable. They share only a point of view that cognitive objects, like categories and other 'states of knowledge', are continuous and dynamic, rather than discrete and static. The notion of a 'physical symbol' as a model for cognitive objects may be too narrow. Van Gelder and Port are editing a book of specially written studies to be published by MIT Press in his. The book explores these issues by bringing together both experimentalists and theoreticians.

Manuscripts

Van Gelder, Tim and Robert Port "Beyond Symbolic: Prolegomena to a Kama-Sutra of Compositionality." To appear in Vasant Honavar and Leonard Uhr (eds.), *Artificial Intelligence and Neural Networks: Steps Toward Principled Integration.* (Academic Press; New York).

Port, Robert F. (1992) Challenging readings collection for cogritive science: Review of Readings in cognitive science: A perspective from psychology and artificial intelligence. by A. Collins and E. E. Smith. *Journal of Mathematical Psychology* **36**, 294-296.

Port, Robert and Tim Van Gelder (to appear, 1994) *Mind as Motion: Dynamical Perspectives on Behavior and Cognition.* (MIT Press).

Hawkins, Harold, Ellen Covey and Robert Port (to appear, 1994) *Time and Temporal Processing in the Nervous System* (Plenum Publishing, New York)

Training graduate students in cognitive science
R. Port

Port, as Assistant Director of the Cognitive Science Program at Indiana University, has been supportive of attempts to find external funding for students in our graduate and postdoctoral training programs.

VII. Speech Research Laboratory

D.B. Pisoni

Ongoing research in the Speech Research Laboratory is concerned with a wide range of basic and applied problems in spoken language processing. All of these include research on speech analysis, synthesis and perception. Several recent projects have been concerned with spoken word recognition and lexical access as well as spoken language comprehension.

A long-standing research interest has been the development of evaluation and assessment techniques to study the perception of synthetic speech produced by rule. Studies of phoneme intelligibility, word recognition in sentences and comprehension are carried out to learn more about the differences in perception between natural speech and various kinds of synthetic speech produced automatically by rule using several text-to-speech systems. This work also involves studies designed to examine speech perception under high information load conditions, in order to learn more about how listeners allocate processing resources when the signals do not contain the redundancy of natural speech. Other studies are concerned with developing new methodologies to assess the real-time comprehension of fluent passages of connected synthetic speech produced by rule.

We have been working on a variety of issues related to variability in speech perception, particularly variability related to differences in speaking rate and differences among talkers. Our recent findings have shown that very detailed information about talker and rate variability is encoded into representation in long-term memory. These results raise a number of important issues about perceptual normalization in speech and the role of source characteristics in encoding and representation of phonetic information in memory.

Finally, we have a long-standing interest in perceptual learning, particularly as it might be applied to the reacquisition of non-native phonological distinctions. A major project has been concerned with the acquisition of English /r/ and /l/ by native speakers of Japanese.

The Speech Laboratory is well-equipped with extensive hardware and software for presenting complex acoustic signals to subjects and recording their responses in real-time. Three PDP-11/34 computers are used for perceptual experiments with human observers. There are also extensive computer resources for analyzing acoustic waveforms and generating experimental signals with a variety of speech synthesizers. In addition to the PDP-11/34 minicomputers, the lab currently has a dedicated DEC VAX-11/750 computer system and three DEC VAX work stations that serve as dedicated speech processing stations. The SRL VAX serves as the main computing facility for researchers in the Speech Lab. Each member of the laboratory has a CRT terminal at his/her desk. Additional graphics terminals are located throughout the lab and in several offices in the Psychology building. All computing facilities in the lab are interconnected using Ethernet. In addition, the Speech Lab VAX is interconnected to the campus computing system to facilitate transfer of files to colleagues in other laboratories, both on campus and at other institutions.

Detailed reports of research in the Speech Lab are not included here, in part because that work is more fully described in the annual progress report series entitled *Research on Speech Perception.* Institutions and individuals may obtain copies from the Administrative Assistant, Speech Research Laboratory, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

Research in the Speech Lab has been supported by grants from NIH and NSF and contracts from the U.S. Air Force Office of Scientific Research.

VIII. Visiting Scientists in Human Factors:

Gilbert Ricard

Summary

During my stay at Indiana University I reviewed human factors programs at a number of Universities, and catalogued academic programs that offer the Ph.D. degree in human factors. To these lists, viewpoints from a variety of sources have been added to characterize the field of human factors and the training of its specialists. This was done to convey the diversity of activities identified as human factors work as well as the variety of opinions about it. A good deal of that work benefits from an appreciation of several disciplines; however, many of the best practitioners of applied science have been trained in a single discipline (typically either experimental psychology or engineering). "Interdisciplinary training" should give students an appreciation of other disciplines but not necessarily attempt to endorse expertise in those fields.

Except for programs deliberately designed to communicate academic work to industrial needs (and support the resulting interest from industry), the institutions all have the sole purpose of engaging in contract work - mostly research and development. The list is probably not exhaustive. The work in human factors is performed by four types of organizations: government laboratories, groups within the engineering departments of an industry, contract research and development businesses, and the institutions listed. The institutions are basically competing in the same market as the contract research and development businesses. Their strong points are that their costs of doing business are lower (often they are not-for-profit or are subsidized), they are likely to have specialized equipment or talent which a business could not afford, and they often have some sort of charter for the work they do.

All of the institutions have provided materials. Some of the documents are for marketing and some contain proprietary information about charters or finances. All of this material is on file at the office of the Institute for the Study of Human Capabilities.

At the time this review was being completed, the directional attention of the Institute was shifting from the broader area of human factors to human/computer interaction. Although this changes the organization's interest in specific institutions, it should have little effect on the section containing suggestions. They remain the same.

Human Factors Institutes

Aviation Research Laboratory
University of Illinois
Champaign, IL

Center for the Application of Human Factors in Aviation
University of Central Florida and Embry-Riddle University
Daytona, FL

Center for Ergonomics
University of Michigan
Ann Arbor, MI

Institute for Cognitive & Decision Sciences
Straub Hall
University of Oregon
Eugene, OR

Institute of Safety and Systems Management
University of Southern California
Los Angeles, CA

Institute for Simulation and Training
University of Central Florida
Orlando, FL

Management Systems Laboratories
Department of Industrial and Systems Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA

University of Dayton Research Institute
University of Dayton
Dayton, OH

University of Michigan Traffic Research Institute
University of Michigan
Ann Arbor, MI

UNC Highway Safety Research Center
University of North Carolina
Chapel Hill, NC

Center for Technology Transfer
University of Pennsylvania
Philadelphia, PA

COSMIC
Computer Services Annex
(NASA-affiliated)
The University of Georgia
Athens, GA

Industrial Liaison Program
Massachusetts Institute of Technology
Cambridge, MA

Office of Technology Licensing
Stanford University
Palo Alto, CA

Ways the Institutes Differ

1. Relation to Universities

The institutes listed above differ along a number of dimensions, and it is worth discussing some of them. One way they differ is the degree to which they are operated by personnel of a university and controlled by policies of that university. Some of the institutes, such as the Center for Ergonomics at the University of Michigan or the Institute for Cognitive & Decision Sciences at the University of Oregon are wholly "owned" by (or evolved from) an academic department within a university. Their purpose is to accept projects and funds, employ people to do the work, and in general act as a manager for the work the institute does. Members of these institutes are faculty scientists who propose and then take responsibility for the performance of projects that are done in their laboratories typically by graduate students.

At the other end of this continuum are groups that are only loosely attached to a university and their purposes are usually closer to those of business. They may be like MIT's Industrial Liaison Program which acts as a marketing organization for the skills and products of the faculty, or they may be like COSMIC which distributes (under contract) software developed with tax money at the various NASA research centers. NASA's Ames Research Center, by the way, has appointed various places a "Center for Excellence in (space or aeronautics). Usually these are one individual's laboratory, and the designation is to make it easy to fund them directly, but it appears that they act much as independent grantees. Typically though, these more peripheral arrangements perform services for the university. Here also are included the various technology transfer offices that license patented material, try to support small businesses based on university work, and manage consulting arrangements.

Between these extremes are the rest of the group. Some are like Management Systems Laboratories (sheltered by the university and engaging in business), some are like the Institute for Simulation and Training where the staff are wholly employed by the institute, and some are like the Institute for safety and Management Systems where the institute provides courses and degree programs aimed at a particular sector of industry.

Last, mentioned as a separate case is the University of Oregon's Institute for Cognitive and Decision Sciences, which is a member of a consortium of similar groups funded by the McDonnell Foundation. All of the member groups are "academic" institutes so they are closely attached to their universities, but there is strength in numbers and it appears that the advantage such an arrangement has is the internal bargaining power afforded by long-term reliable funding.

2. Relation to Industry

The institutes differ also in the relation of their work to industry. Some of the groups were started at the specific request of a member of an industry, a state government, or a Department of Defense group, but most were not. Usually, it was the interest of a single individual, but regardless of how they were started, the real point of comparison here is the degree the work of the institute is aimed at a specific source of funding. Probably the best example is the Aviation Research Laboratory at the University of Illinois where the equipment and staff were chosen to build the capability of performing aviation human engineering work. The presence of a state and national industry has

provided careers for the graduates and there are many sources for funding (such as the DoD, DoT, FAA, and NASA) that have contributed problems and resources. The Institute for Cognitive & Decision Sciences fits this model (in a backwards sense) - their research fitted the goals of the funding organizations and so made a good match. The institutes at the University of Michigan (the Center for Ergonomics and the Traffic Research Institute) were also created for specific markets. The ergonomics group was basically started by the Ford Company and the traffic research group has long been funded by the Department of Transportation.

At the other end of this dimension are groups like the Institute for Simulation and Training and the University of Dayton Research Institute. Both of these were started to cater to a specific customer, but within the mission of that organization, the institutes' work is fairly general. UDRI does physical science and engineering as well as supplies on-site skilled employees to government laboratories and the IST has projects on computer science as well as training methods.

All of these groups have the potential of providing a fairly broad range of "services" depending on the skills of people at the various universities, apparently no group explicitly does this. Probably this is just because they have all followed the path of least resistance and have done whatever work seemed to be in demand. While it is certainly easier to market work geared to a customer's needs (especially when the customer is in the business of sponsoring just that sort of work), the original goal in forming Indiana's human capabilities institute was to interest a major research university in applied work, and the need for that still exists. The marketing problems are those of finding the people who need the work, finding them at the right time, and building a record of successful projects. The ideal solution is to have the market come to Indiana's institute, knowing its capability and confident that it can provide a solution in the form that is needed. This happy state, though, would require patience and an investment on the part of the university. Those institutes that have survived and have become relatively permanent parts of their institutions have done so because they met needs both within and external to the university and they generated funding for work that was compatible with the preferences of its members.

3. Mechanisms for Visibility

Almost all of the groups surveyed used a variety of mechanisms to get visibility for work done, but which also advertised the potential for similar work for the future. One of the most common tools is the brochure. Typically these are at least four-color prints on stiff glossy paper, often they are some sort of multiple-page fold-out arrangement, and occasionally they contain inserts. Some used a magazine format - much like a yearly stockholder's report - but all had photographs to illustrate products, capabilities, or the people doing the work. MIT's Industry Liaison Program uses an informal tone for the text in its somewhat monthly newsletter partly to reduce the apprehension people in industry might have for contacting well-known researchers. These brochures are given to those who request information about the institutes, but a typical use of such material is to rent a booth at a conference and give them away. Usually, the glossy packets are expensive and are used for potential customers, but an inexpensive handout is the format used on its "cheat sheets" by Indiana University's computing center - 8 1/2" by 14" stock fan-folded to be pocket size. Always, the attempt is to get a name and telephone number to someone who actually may be interested.

Another obvious method for visibility is the word-of-mouth advertising that comes from a flow of visitors to the group and from graduates who inform employers about work the group can do.

These methods are slow and unreliable, but in the long run, they are important ways to disseminate information.

Papers and contracted reports are often distributed to a list of people who may be interested in the work or who are sponsors of similar work. In the government, this is the way technical reports are distributed, and one of these lists is the Office of Naval Research's distribution list for the cognitive research they sponsor. Many groups have newsletters or lists of papers and reports they will provide also. All of this attempts to get information into the hands of those that want it, but it is a useful form of advertising.

Another tool for visibility is the yearly meeting. Usually these take the form of project reviews for sponsors or a meeting on a topic, such as human error. A useful role for a meeting, though, is its way of advertising that a group performs certain work, and like the distribution lists for technical reports, the trick is to get the right people to come.

Last, as institutes become large and have commercial business, employing an individual to be a marketeer is a strategy that is useful. The work is tracking sources of funding, getting information about potential customers, making sales presentations, and in general, acting as an "interface" between the technical members of the group and the commercial world. Large businesses who do contract work for the government typically employ such people because the information and analyses they provide keeps the business competitive.

4. Economic Dependency on the University

In this dimension information is sparse. The only datum available here is that the Institute for Cognitive & Decision Sciences at the University of Oregon receives $20,000 per year from the university to fund a part-time secretary and travel costs for visitors. The rest of their funding, about $300,000 per year, comes from the two foundations. It appears that the more "focused" institutes (such as the Institute for Simulation and Training or the Aviation Research Laboratory) have larger incomes and depend very little on university funds. Management Systems Laboratories at Virginia Polytechnic Institute and State University has the agreement that the university's general fund pays salaries during periods of insufficient work, but the institute was built with a $1 M per year contract from the U. S. Department of Transportation so they have not had to depend on the university. This seems to be true of most groups. If they had to depend on their university, they probably would not exist.

5. Types of Services Offered

The services institutes have offered range from basic research to consulting and acting as "body shops" to provide skilled personnel under contract. Typically, most do applied research as they are funded to do, but certainly basic research is represented. The cognitive and decision sciences institute at Oregon does basic research and apparently institutions such as MIT do a lot of basic work that is funded or sponsored by an industrial client. Certainly their Industrial Liaison Program has been a success. The Oregon institute is the closest to the group here at IU in the work they do and the interests of the members.

Groups flourish that fill a need in the market place. In this case, institutes exist because they perform a service that is needed. When the service is clearly related to a market, then it is easy to

see how the institute sustains itself. Thus, most of these institutes have a "focus" or specialty - it could be aviation, automobile design, simulation and training, or whatever - that reflects their intended market. They in turn are supported by work in that marketplace. One role of a common theme for these groups is the internal cohesion it provides. It gives the group its reason for being, but it also is the selling point for the world external to the university. Along with providing graduates practical experience and making the "marketing" of the work easier, having a cohesive topic for the work of an institute also allows the more informal word-of-mouth communication to be more efficient. Graduates become employed by an industry, tell others of work at the institute, encourage them to take their problems to the institute, and so on.

The Indiana University Model

The Institute for the Study of Human Capabilities started as part of an Air Force Office of Scientific Research program to get the faculty at a research university interested in applied problems. The institute sponsored several meetings, has supported a number of visitors, and has sponsored some applied projects by its members. The world has changed a bit since the time of the initial funding, but there is good reason to continue and possibly try to expand the original goal of the organization. The Department of Defense as well as the traditional grant institutions have had their budgets reduced, and the prospect for relative increases of these budgets seems slim for the rest of the decade. Interest in applied research, then, represents a means of supplementing the traditional sources of funding for research that are strained to support even a proportion of the worthwhile proposals they receive.

The vision for the Institute is to use skilled faculty to solve real-world problems that fit the various interests of individuals. This is in keeping with the University's basic mission of research and teaching; it only broadens the base of the source of problems and funding, but it serves several goals. First, inviting applied work is a means of obtaining additional support during times of reduced government spending on science and education. Second, acquainting faculty and graduate students with applied problems historically has been a stimulus for further basic research. One only has to reflect on the effect each of the world wars has had on the development of Psychology to see that solving real problems quickly defines the technology produced by a science. Last, during this period of slow growth, experience at applied research broadens the employment prospects of recent graduates - increasing the likelihood they will be able to continue the science in which they were trained. The institute with its current members can provide competence in four areas: 1.) cognition and decision-making, 2.) sensation and perception (audition, speech and hearing, vision, skin senses, and language), 3). mathematical modeling, and 4.) computer science. There has been some interest in using human/computer interaction as a topic of concern for a variety of groups on the Indiana campus, so that in addition to the topics mentioned, the institute could unite interests from the Education, Mathematics, Philosophy (logic), Language, Computer Science, and Psychology departments. Either way, the group could provide interdisciplinary work to customers and experience to graduate students.

Such a group could seek work from industry and government laboratories as well as from those who already contract with these groups. That is, the institute can vie for contracts or could sub-contract work in its specialties.

Suggestions

Several suggestions are outlined here, all having to do with obtaining visibility for an organization at IU and in supporting the work involved. They are divided into those that are relatively inexpensive and those that are not.

Low-cost alternatives

1. Brochures

The brochure is a traditional method of communicating to potential customers. It should tell what the institute does, how it was formed, and what it can do for a customer. It has to encourage someone to call on the telephone and get more information. The University of Oregon's brochure uses color photographs and drawings on heavy, glossy paper, and it's fan-folded to provide more surface for material. In addition, it has a pocket for additional detailed material about specific projects. A good suggestion might be a brochure that is a combination of this model and the MIT newsletter. Included could be photographs of the members of the institute, their telephone numbers, brief but chatty descriptions of work that can be applied, and some mention of the range of problems that the institute is prepared to consider. The brochures could be used (1) as an enclosure to any first contact with a customer and (2) as material to distribute at conferences. Remember, the people who need to know about the institute are potential customers, not present colleagues. Distributing material like this at meetings of the Psychonomic or Acoustical Societies will not be nearly as effective as going to meetings where applied research is discussed. Examples are meetings of societies such as:

- Human Factors and Ergonomics Society
- SIGCHI - a special-interest group of the ACM
- American Institute of Aeronautics and Astronautics
- Institute of Electrical and Electronic Engineers meetings
- NAECON - This is an Air Force meeting in Dayton in the spring
- NTSC Tri-Service Training Conference.

There are many such meetings regularly scheduled, but there are also a variety of special-purpose meetings where potential customers could be interested. Perhaps government agencies such as AFOSR, ONR, and many of the government laboratories can help here. After a brochure is available, someone could spend a year touring various meetings presenting a short talk about the institute and staying a day to distribute brochures. Often large marketing meetings rent booths where representatives of a business can distribute material and chat with interested persons. If it's the right meeting, spending a day in a booth might be worthwhile.

2. Letters to Businessmen

Along with the brochure, a letter is a traditional means of contact. A brochure typically is a "bottom up" approach - it is designed for a particular customer. In contrast, perhaps a letter to leaders of business as a "top down" method of generating interest at the highest levels of industry could be of use. A letter would have to present a dignified introduction to the institute and its methods with an invitation to contact someone and continue the interaction. The goal here is to announce the institute to a wide audience and to

pique someone's curiosity to see if knowledge from basic research really may be useful. Leaders of business, typically, are not shy about admitting their own ignorance or in using ideas if they seem useful.

3. Advertisement

The institute might also consider a well-placed advertisement - in a magazine such as Forbes or in newspapers such as the Wall Street Journal or the New York Times. An innovative advertisement may operate like a letter to business men; it may catch someone's fancy when they need help. Good ideas for advertisements are all over. The advertising design council publishes a yearly review of the best ideas, and many industry trade magazines contain useful formats. There is a magazine "Aviation and Space Weekly" published by McGraw Hill that has some memorable advertisements in it - mainly because some sectors of the aerospace industry know the value of advertising. One ad sticks with me - it showed an engine block or something like that flying across the heavens with the caption "Metals That Fly!" It was for a precision investment casting company. One can easily imagine a headline such as "Ask not what your business can do for Indiana University, ask instead what auditory psychophysics, cognition, language & computers, and decision-making can do for you." with some text about the institute and an invitation to get more information. Inventing advertisements can be fun, but more to the point, a well-placed one may generate the appropriate interest.

4. Summer Courses

The University of Michigan, UCLA, and MIT have offered short (typically one-week) summer courses that review a topic. Usually these are aimed at practicing engineers, priced for their businesses to write them off as training, and presented as a "service" to the industry. A subtler reason for them is that they advertise the skills and points-of-view available at an institution for consulting or applied research. Typically these are given when there is dormitory space open for the visitors and to the extent they can be treated as a group - by living in the same dorm and eating at the same places - many ties are formed that are useful after the course is over - useful to both the participants in the course and the university that sponsored it. A course on a topic in applied cognition, such as "Approaches to Cognitive Engineering" would be a good way to develop a constituency for a developing applied program. For years, Dick Pew taught a one-week course on "Human Factors and System Design" at Michigan's summer school, and a good proportion of the practicing human factors engineers in industry have taken it. In turn, it seems that Dick occasionally gets calls for help from these former students and is able to keep abreast of a variety of current work. Many societies sell their membership lists so advertising such a course would not be difficult. When the reason is in the interests of its members, The Human Factors and Ergonomics Society will print its membership list on sticky labels for a nominal charge. Other groups, such as the IEEE and SIGCHI, support the mailing of professional announcements to their members also.

5. Visits to Industry

Many industries have "slots" for visitors for a period of time - a year, a summer, a week. These are sort of the industry equivalent of the NRC post doctoral fellowships that NASA uses to get someone started at one of its research centers. Obviously, many of these are created because of interest in a specific individual, but a stay at a business, even for a short period is a quick way to see what problems are real. Apple Computer Corp., for instance, has had a variety of people act as consultants by staying for a while. They also

have an advisory board of people from industry and universities that used to meet once a year or so. Either way, they got a collection of points-of-view, but they also influenced the work that some of these people went on to do. The point is that if one really wants to bridge the gap between basic and applied work, one should give it a try. Also, catering to industries that have such openings is a way to get graduates employed. A graduate student might fill one of these openings and turn it into permanent employment.

6. Conferences

A conference is a good way to establish "ownership" of an area, so there is a lot to be said for a conference series. To date, the conferences the Institute has sponsored have largely been directed at other academics, with some attendance from Wright-Patterson AFB. Most important, the proceedings were not published, so the spoken papers are lost. If the institute grows, a good way to maintain the growth would be to initiate the "Indiana Applied Research Conference" where the best of recent research (whose application is obvious) can be presented and the invitees are businessmen, government program managers, and the like. It could be somewhat of an "Annual Review" format to highlight work across the country of which the decision makers of the world should be aware. The point is that is would provide publicity for the institute and Indiana University, and maybe attract funding. The disadvantage, though, is that to this well is a lot of work.

A bit more to the point since the above was written would be an "Indiana Human Computer Interaction Series" that would attract people from industry as well as academia, much as the SIGCHI meeting does. SIGCHI's attendance is almost exclusively computer programmers, yet the special-interest group deals with human interaction with machines. A conference series that publishes the papers, so there is a record, could easily place Indiana University at the fore of this literature - especially if the emphasis is not to provide a forum for just more papers on "A computer software architecture for. . . (one thing or another)." Human limitations that should effect system design are not well understood or widely discussed outside of Psychology, so that by sponsoring a conference series, Indiana University would be doing a service for the world as well as for its own students and itself. Right now, the SIGCHI and Human Factors Proceedings are the only yearly outlets for such material. (There are some journals - the International Journal of Man-Machine Studies, the International Journal of Human/Computer Interaction, etc.). Also, a printed forum would provide a place for graduate students to get a start at writing papers. Typically, conference proceedings are not reviewed well, so a series with some editorial requirements for its papers would be welcome. Industry always seeks serious help for its goals, and a series that presents useful information should gain popularity. One of the reasons for SIGCHI's success is that its the one place that people actually designing interfaces defined by software can get together and compare experiences. Thus, a lot of what is "current good design" is part of the informal lore that is discussed at this meeting. Having this sort of discussion at a university group that studies human capabilities should provide the stimulus for innovative research work.

In addition, there are some points to keep in mind. It would be prudent to schedule a meeting at a time of the year when people would like to visit central Indiana - in the fall, for instance, when the foliage would be an attraction. It also is prudent to be aware of the schedule of other related meetings - just to avoid conflict. Last, as an aside, it is worth noting that a good acronym is valuable - both for the title of a meeting as well as the name of the institute itself. It is worth finding names that are short and which make pronounceable

acronyms. It is also worth remembering the Navy's rule to leave a vowel in contractions (some of which became official), so that the Commander of the Naval Air Forces, Pacific Fleet becomes COMNAVAIRPAC, who, in turn, is affectionately known as AIRPAC to his friends. These sorts of contractions are used because they are easy to remember and they are fun, but in addition, they serve as a jargon to reduce complicated references to individuals or offices. As the business and government market is more heavily tapped from, there will be more people who think using such short-cuts, who will create their own if they are not provided. The art is to make one that is short and pronounceable that also is not silly.

High-Cost Alternative

Hire a Manager/Marketeer/Administrator

Each of the mechanisms above requires effort, probably more than anyone wants to devote to it. One alternative is to hire an administrator or a part-time faculty person who has at least half-time to devote to the institute. Indiana University has a technology transfer office that performs a marketing function for the university, but it is a new office and probably has not developed to provide the specific attention needed by the human capabilities institute. Marketing is time consuming and cannot be done well unless the time and motivation are available. Typically, the world will not by itself decide that Indiana University is a place to approach for work applied to its problems. It will have to be encouraged, and this is always a bit of an uphill battle. Someone will have to track programs within the government, contact people who might use the institute, and tend to the politics and administrative work. This may not be as difficult as it sounds, Wright-Patterson AFB is not far, and almost anyone there would be aware of the state of programs that are related to their work.

A last thought about doing business is to decide how to do it. Although it sounds a bit formal, some sort of agreed-upon set of procedures would be a good idea, just so all members of the institute present the same face to the world. Should someone call, what next? How to establish a working relationship? Perhaps a useful approach would be a sequence where telephone discussions are followed by a potential customer's visit to IU. If that proves fruitful, then maybe an investigator should visit the customer to learn even more about the problem. Last, if it appears that some research will help, then the customer can fund it. Prior to any interaction with potential customers, though, it would be beneficial to agree on costs and how to develop quotes for time for any of the steps above.

Appendix A

Human Factors Courses, Programs, and Training

There are three documents that may be helpful in determining what various graduate programs in human factors are like, and what they possibly should be like. The Human Factors and Ergonomics Society publishes two of them. One is the *Directory of Human Factors Graduate Programs in the United States and Canada*, which lists descriptions of departments that offer human factors training, their admission requirements, some of the course offerings, and a list of the faculty. The other is a set of guidelines the Society uses to evaluate graduate programs in human factors. It is the *Human Factors Society Accreditation Self-Study Report Guide* of 1990, and it gives what some feel is current adequate preparation for the discipline (at least broadly defined). The third document is a 1992 report by the Human Factors Committee of the National Research Council entitled *Human Factors Specialists' Education and Utilization: Results of a Survey*. It provides the results of a National Research Council study comparing human factors practitioners' training and daily work activities. These three documents are also deposited at the Institute for the Study of Human Capabilities at the Poplars Research and Conference Center.

The lists below are from descriptions (from the *Human Factors Society* Directory) of PhD programs in Human Factors that mentioned required or elective courses. Not all of them did so the list is best taken to illustrate the variety of topics that are put together as Human Factors. The lists do not differentiate whether or not it was an engineering or psychology program that offered the course.

Required Courses

1. Courses Having an Engineering Flavor
- Research Methods in Engineering Psychology
- Human Performance in Systems
- Engineering Psychology
- Human Factors in Systems Design
- Displays and Controls

2. Experimental /Cognitive/Physiological
- Cognitive Bases of Behavior
- Physiological Psychology
- Human Performance
- Learning and Memory
- Sensation and Perception
- Applied Experimental Psychology

3. Social/Personality/Industrial
- Social Psychology
- Organizational Psychology and Personnel Selection
- Ergonomics
- Environmental Psychology
- Individual Differences

4. General
- History and Systems

Foundations of (or Introduction to) Human Factors
Research Methods
Quasi and Non-Experimental Methods
Human Factors Research Methods
Statistics - usually 2 or more courses - through multivariate analyses

The main point is that the "Core" of almost the entire profession is training as an experimentalist. Different programs, depending largely on the interests of their faculty, emphasize the different groups of courses differently, but certainly most programs required courses from group 2 and quantitative methods courses from Group 4. The only exceptions seemed to be engineering programs specifically aimed at training practitioners for design work or programs with an emphasis on health and safety. The topics that human factors specialists consider change so rapidly that training on any one is of little value. They are far better prepared by knowledge of measurement and experimentation, the facts of current experimental psychology, and an understanding of how to define and choose problems for work.

Electives

1. Cognitive/Computer Related
- Human-Computer Interaction
- Applied Human Information Processing
- Mental Models
- Cognitive Engineering
- Artificial Intelligence
- Attention and Information Processing

2. Applied Experimental
- Psychophysics and Scaling
- Spatially Coordinated Behavior
- Skilled Performance
- Visual Perception
- Audition and the Effects of Noise
- Human Memory
- Software Psychology
- Judgement Processes and Decision Research
- Mathematical Models of Measurement

3. Engineering/Systems Design
- Aviation Psych
- Display Design
- Complex Systems
- Simulation and Training Systems
- Operations Research
- Simulation and Modeling Techniques
- Human Error
- Biomechanics
- Task Analysis

4. Personnel/Social/Environmental Factors
- Personnel and Training Systems
- Work and Job Design

Environmental Design
Social and Environmental Factors in System Design
Managing Technical Innovation
Industrial and Organizational Psychology
Multivariate Statistics

Here the grouping was a bit more arbitrary and my divisions tended to reflect how topics are related currently in the field. Some of these courses, such as "Models of Measurement", seem to be extensions of a core, while others, such as "Task Analysis," are difficult to imagine as courses. Others, such as "Display Design" represent topics that have economic impact and which are becoming "academicized" as principles governing layout and content are abstracted and tested. The diversity of topics both shows the varied interests of teaching faculty and the nature of the discipline. Lots of topics seem to fit between the interests of psychology and engineering. Duplication of courses on this list with the previous one merely indicates that one program's requirements were another's electives.

Below are listed the 65 schools that offer a PhD in Human Factors. They are divided into those that offer the degree in an engineering department and those that offer it through a psychology department. Typically the engineering programs stress safety, work analysis, and system design, and the psychology departments treat human factors as applied psychology. The (*) indicates that there is an additional department at the school (typically it was either engineering or psychology) that offers a degree in Human Factors.

Engineering Programs (35)

Auburn University
Iowa State University
Kansas State University*
Louisiana State University
New York University
North Carolina State University
Northeastern University
Ohio State University
Pennsylvania State University
Purdue University
State University of New York at Buffalo
Technical University of Nova Scotia
Texas A & M University
Texas Tech University
University of California at Los Angeles
University of Cincinnati
University of Connecticut
University of Illinois
University of Iowa
University of Louisville
University of Lowell
University of Massachusetts
University of Miami
University of Michigan

University of Nebraska-Lincoln
University Pennsylvania
University Southern California
University of Texas at Arlington
University of Toronto
University of Utah
University of Washington
University of Waterloo
University of Wisconsin-Madison
Virginia Polytechnic Institute and State University
West Virginia University
Wichita State University

Psychology Programs (24)

Catholic University
George Mason University
Georgia Institute of Technology
Kansas State University*
Miami University
New Mexico State University
Ohio State University*
Old Dominion University
Pennsylvania State University*
Rice University
Stevens Institute of Technology
Texas Tech University*
University of Central Florida
University of Cincinnati*
University of Connecticut
University of Illinois*
University of Iowa*
University of Louisville*
University of Maryland
University South Dakota
University Southern California*
Virginia Polytechnic and State University*
Wichita State University*
York University

A Program

Appendix A of the HF&E Society's accreditation report guide provides a nice quote to define human factors specialists and their training. "Human Factors is concerned with the application of what we know about people, their abilities, characteristics, and limitations to the design of equipment they use, environments in which they function, and jobs they perform." Thus a program to train practitioners "should contain knowledge about the properties of people, research methodologies, analysis and design methodologies, and some basic skills in mathematics, computers, writing, and speaking. It should contain practical experience in defining and solving human factors problems.

Finally, it should include research experience." From this point-of-view, the Human Factors and Ergonomics Society suggests that a training program address these six topics.

1. **Knowledge about properties of people**
   Of the various ways to divide information about human abilities and actions, two merit emphasis in a training program: one is to emphasize the human being as a processor of information and the other is to regard him as a physical engine (a source of action).

2. **Research Methodologies**
   This is the standard set of skills about formulating problems, designing studies and analyzing them.

3. **Analysis and Design Methodologies**
   Here the emphasis is on techniques such as mission and task analysis, function allocation, and the art of trading safety, cost, operator workload, and performance that goes into system design.

4. **Skills**
   In addition to an emphasis on written, verbal, and mathematical communication skills, Human Factors specialists should have some level of familiarity with computers.

5. **Research Experience**
   The Society and most practitioners feel that competence at research is paramount. The discipline is new enough that practitioners will always be reading research and many will be employed to perform it. Either way, more than a casual acquaintance with research is desirable.

6. **Practical Experience**
   Human Factors is an applied field so that practice at identifying and defining problems is as much a part as the skills to solve them. Appendix C of the HF&E Society's accreditation document lists a number of the means developed to involve students with real problems.

The above six factors were mentioned by Fisk and Fisher in their paper on *The Development of a Human Factors Program at Indiana University*, but they are listed here again as some (such as #3 and #6) are difficult to provide in an academic program. This is probably the best reason that programs such as the ones at the University of Illinois have been so influential - there is a lot of on-going contracted work with which students can become involved and it all deals with problems of one applied area - aviation - that is a large national enterprise that can employ them. A good portion of the people in the aviation human factors field have come from the University of Illinois - probably for several reasons. One is the focus of both the engineering and psychology Human Factors programs on aviation. The "critical mass" of people and equipment has made it easy to attract funding. Another is the availability of each program to students in the other - psychology students can learn about engineering techniques and approaches in real settings - an appreciation that employers value. Last, (and this is one of the strengths of Indiana University) Illinois is a major university that attracts bright students who probably will succeed in whatever situation they find themselves. The existence of a contract-supported laboratory tends to make students aware of funding and who does it (and how

to get it), and after a while, the reputation of the place makes it easy for students and employers to find each other.

Last, the National Research Council was requested by the Army Research Institute to examine human factors practitioners' work and training and make determinations of the requirements for such people in the future. The resulting telephone survey sampled people obtained from the membership lists of a variety of organizations, and survey was limited to those the felt that they were doing human factors work. The sample was not limited to members of the Human Factors and Ergonomics Society, for instance, so the work included as "human factors" was broadly defined. In addition, the data were divided according to whether the respondent was a working specialist or supervisor.

The report drew two conclusions and made several recommendations, some of which might be helpful here. First, they found that the majority of people worked in six areas: computers, aerospace, industrial processes, health and safety, communications, and transportation, and that they were a diverse group. Many considered themselves part of a traditional profession, such as psychology or engineering, and only about 40% identified with Human Factors as a profession. The NRC's point was that a variety of skills are employed in human factors work and that this posed a problem for the standardization of training. The other side is that a particular program may view itself as training people for only part of the human factors profession. Second, the study found that supervisors felt that they were poorly prepared for supervisory responsibilities and that new graduates, in general, were ignorant of the "business" side of the discipline. In addition to ignorance of the mechanics of doing business, recent graduates were well schooled in theory and research but they were not prepared for the evaluation studies required in the workplace.

The NRC report lists six recommendations. They are:

1. Training for the profession should be interdisciplinary. System integration requires extensive communication across disciplines so that both engineering and psychological issues are addressed knowledgeably, and the NRC recommends that training programs provide cross-discipline experience, one way or another, to foster the understanding and appreciation required by such work.

2. Use a core curriculum. This recommendation was made because of the diversity of skills and backgrounds that appear in the profession, where a set of elective courses can keep the core responsive to the needs of employers, and a curriculum built about a set of required courses supplemented by electives is one way to do this. A glance at the required and elective courses taken from the directory of graduate programs in human factors shows that across most programs, this has been the path chosen. Some schools had no requirements, but most required some courses in psychological theory and research as basic to a program. I'm sure Indiana University would be comfortable with that approach. A senior-level or first-year graduate course could cover the basics and a flexible set of seminars would address particular topics of interest.

3. Develop and encourage internship arrangements. This recommendation was to solve two problems: first, that students often did not have much understanding of how real-world organizations addressed problems, and second, that their dissertations were often far removed from practical applications. This also is the main task for the Institute - to bridge the gap between the problems of industry and government and the capability represented by IU faculty

and students. To date, the most successful of such "bridges" have had a subject of mutual interest where the university developed particular capabilities that enabled it to become noted as a center for particular work. In human factors, this approach has been to develop expertise in one of the six areas listed in the NRC's first conclusion. Examples are the Aviation Research Laboratory at the University of Illinois and the Traffic Research Institute at the University of Michigan. Both of these have received funding from both industry and the appropriate government organizations.

Aside from questions of focus and funding, a separate issue is the mechanics of operating internship arrangements at IU where it seems there are not many sponsors nearby. Students work on a dissertation, for instance, away from the university, often find themselves caught between the political or funding limitations of the sponsoring organization and the values of the university.

4. Support Training. Another of the NRC's recommendations is related to #3 but was aimed at sponsoring activities. This was to create graduate traineeships in human factors. The emphasis here is to encourage an interdisciplinary view of the field and of development work. Typically, graduate programs have poorly bridged the gap between theory-based work and systems integration. More and more, good design reflects well-integrated systems, not the application of a particular discipline.

5. Extend human factors to new areas. The main reason the "human factors" point-of-view has remained popular is that it produces better systems or products. Most of its practitioners, though, have remained in the six areas mentioned earlier where the cost of products or system failures is high or where a large market exists for particularly easy-to-use products. The aviation and computer industries obviously fit these criteria. International competitiveness will eventually force other industries to make their designs more user-centered and the NRC felt that universities could prepare people for an expanded market their skills.

In addition to these recommendations there were several others about encouraging women and minorities into the field, continuing the running evaluation of the field of which the NRC study was part, and providing supervisory training to graduate students. This last comment was made in response to human factors supervisors' comments that they and the people they supervise were poorly prepared for management responsibility.

6. Provide supervisory training. This recommendation was in response to the comments of supervisory people who felt management training should have been part of their schooling. It seems that recently many graduates from human factors programs are employed by small businesses that do not provide training when an individual is asked to supervise others. Large ones do, and there is an industry that provides training courses on management and supervision. This recommendation may be surprising, but the human factors profession does have a strong business flavor and universities, typically, have not been places where students learn to mix the values of a profession with those of business.

These recommendations may just reflect the times, or perhaps what particular members of the NRC's study committee wished to emphasize. Either way, a human factors training program at Indiana University should be aware of these issues and, at least, have taken them into account.

Other Sources of Support

Auditory Research

AFOSR 4962092J0506 9/15/92 - 9/14/94	Perception of Complex Auditory Patterns C.S. Watson, D. Robinson, D. Kewley-Port - $239,000
NIH R44-DC00893 (SBIR Phase II) 1/1/92 - 12/31/93	Indiana Speech Training Aid: Stage IV D. Kewley-Port, Communication Disorders Technology, Inc. - $500,000
NIH 4/1/91 - 3/31/96	Dynamic Attending and the Perception of Patterns in Time G.R. Kidd - $321,317
ONR 12/1/90 - 11/30/93	Models for Continuous Auditory Processing R. Port - $322,390

Vision Research

NSF 2/1/91 - 1/31/94	Physical Constraints on Form: Investigating Visual Information for Event Recognition and the Judgement of Sizes G. Bingham - $175,000
I.U. Dean of Faculties Ventures Fund Award 4/3/92 - 4/3/93	A Study Group on Dynamical Systems Multidisciplinary in Cognitive Sciences Bingham, Port, van Gelder, and Thelen - $2,500
Grant-in-Aid of Research, Indiana University, awarded on August 26, 1992	Visually Guided Reaching Research $500
NIH (NEI) 5R01EY05109 4/1/93 - 3/31/96	Optical and Retinal Limits to Human Visual Performance L Thibos - $676,290

Cognition and Decision Making Research

NSF BNS 911281 8/1/91 - 1/31/94	Stochastic Theory, Method and Experimental Design in the Identification of Mental Architecture James T. Townsend - $249,913
NIH R01 DC00095-22 7/1/86 - 6/30/93	Cutaneous Pattern Perception J. C. Craig - $997,361
NIH R01 DC01577 7/1/92 - 6/30/95	Haptic Perception of Multidimensional Patterns J. C. Craig - $72,952 (Subcontract with Gallaudet University)

NIH PHS NIDCD DC00-111-16
3/1/88 - 2/28/95

Speech Perception and Spoken Word Recognition
D. B. Pisoni - $1,637,392 (Total direct costs)

AFOSR 870079
1986 - 1993

Institute for the Study of Human Cognition
R. Shiffrin - $1,505,000

NIMH PHS Merit Award 12727
1991 - 2001

Information Processing and Retrieval
R. Shiffrin - $1,110,000

NIH TR-MH19879-01
1993 - 1998

Training Grant
R. Shiffrin - $940,417

NSF Graduate Research Training Grant
1993 - 1998

Modeling Human Cognition
R. Shiffrin - 1,100,000

Indiana University
1980-

Luther Dana Waterman Research Award
R. Shiffrin - $13,000

Bioacoustic Research

NIH 1 RO1 NS29467-01
5/1/91 - 4/30/94

Motor Control in Production and Development of Birdsong
R. Suthers - $87,930 (Direct costs - Yr. 1)

Connectionism

NSF BBS
1992 - 1994

A Connectionist Model of the Development of Similarity
M. Gasser, L. Smith - $173,125

NSF Young Investigator
1992 - 1997

M. Gasser - $125,000

ONR N0001491J-1261
12/1/1990 - 11/30/1993

Models for Continuous Processing of Auditory Signals
R. Port - $460,000

NSF 92-04046
8/1992 - 8/1993

Noise and Tone: A Study in Cognitive Ethnomusicology
R. Port, with C. Fales - $23,045

ONR N0001491J-1261
12/1/90 - 11/30/93

Models for Continuous Processing of Auditory Signals
Port - $460,000

ONR
3/15/93 - 9/15/93

Conference on Neural Representation of Temporal Information
Ellen Covey and R. Port - $16,687

NIMH
7/1993 - 6/1998

Mathematical Modelling in Experimental Psychology
Shiffrin, Port, Castellan, Townsend - $237,378

Extramural Activities

C. S. Watson is the director of the Institute for the Study of Human Capabilities and serves as an advisor to the National Research Council's Committee on Hearing, Bioacoustics and Biomechanics (CHABA). He recently served as chairman of CHABA Working Group 95, on Personal Speech Perception Aids for the Hearing Impaired. He is also a member of ASA Standards Committees S3-63 on Acoustical Warning Devices, and S3-76 on Computerized Audiometry. Watson serves as a reviewer for the *Journal of the Acoustical Society of America, Journal of Speech and Hearing Research, and Perception and Psychophysics.*

R. M. Shiffrin serves as the associate director of the Institute for the Study of Human Capabilities. He is the first director of the Indiana University Cognitive Science program and serves on the National Science Foundation review panel for Cognition and Perception. He is consulting editor for *Acta Psychologia, Memory & Cognition, Psychological Review, and Journal of Mathematical Psychology.*

G. P. Bingham is a consulting editor for *Ecological Psychology,* and an associate for *Behavioral and Brain Sciences.* He serves as a referee for the *Journal of Experimental Psychology: Human Perception and Performance; Journal of Motor Behavior; Ecological Psychology; Behavioral Research Methods, Instruments, and Computers; Human Movement Science and for the National Science Foundation, division of Neural and Behavioral Sciences, Program in Language, Cognition, and Social Behavior; Human Factors; Memory and Cognition; Developmental Psychobiology, North American Society for the Psychology of Sport and Physical Activity.* He is a member of the Psychonomic Society, Sigma Xi, the International Society for Ecological Psychology, and the American Psychological Society.

A. Bradley serves as editorial reviewer for the *Journal of Neurophysiology, American Journal of Optometry and Physiological Optics, Vision Research, Journal of the Optical Society of America, Clinical Vision Research, Investigative Opthalmology and Visual Science, Ophthalmic and Physiological Optics, Gordon Heath Symposium Papers, Butterworths Scientific Publishers, Optometry and Vision Science, Behavior Research Methods, Instruments, & Computers, Developmental Psychobiology.* He also serves as special Feature Editor for *Optometry and Vision Science* (Simultaneous bifocal and multifocal vision). He is a grant reviewer for National Science Foundation and NIH. He was recently appointed to the editorial group of the "Dictionary of Visual Science" and served as 1992 General Chair of the Optical Society of America topical meeting: Non-invasive Assessment of the Visual System. He was awarded the Glen Fry Award for Visual Science by the American A[illegible]emy of Optometry in December, 1991; he received the Best Paper Award for 1991 by the Society for Information Display. He is currently writing a book for Optometry students studying for their National Board Exams.

N. J. Castellan, Jr. is the editor of *Behavior Research Methods, Instruments, and Computers and Judgment/Decision Making,* a newsletter. He serves on the editorial boards of *Organizational Behavior and Human Decision Processes, Behavioral Decision Making, Social Science Computer Review, and Interactive Learning International* . He is chair of the Forum on Research Management, one of three standing committees of the Federation of Behavioral, Psychological and Cognitive Sciences.

J. C. Craig recently completed a three-year tenure as Associate Director of the Institute for the Study of Human Capabilities. He serves as a member of special review panels of NSF, NIH, and SBIR as well as having been a member of the NIH Study Section on Sensory Disorders and Language. He recently served on the Task Force for updating the National Strategic Research Plan for the National Institute on Deafness and Other Communication Disorders. He is the recipient of the NIH's Javits Neuroscience Investigator Award, July 1986 to June 1990, and the Claude Pepper Award from July 1990 to June 1993.

M. Gasser served as co-organizer of Midwest Connectfest, a meeting of connectionist researchers in the Midwest. He is a member of AAAI, Association for Computational Linguistics, ACM, Cognitive Science Society, Midwest AI and Cognitive Science Society, Linguistic Society of America, and International Neural Network Society. He has served on the review panel of *Neural Information Processing Systems, Psychological Review, Studies in Second Language Acquisition, Behavioral and Brain Sciences, Cognitive Science, Psychological Review, Computational Linguistics, and Machine Learning.*

S. L. Guth is an ad hoc member of the U.S. Committee of the International Commission on Illumination and a Fellow of the Optical Society of America. He is a referee for grant proposals submitted to NIH and NSF as well as a referee for articles submitted to *Journal of the Optical Society of America, Vision Research, Psychological Review, Journal of Experimental Psychology, Perception, Journal of Color Research and Application, Perception & Psychophysics, and Science.* Dr. Guth has a strong affiliation with the vision group at the Laboratory of Applied Physics of the French Center for Scientific Research in Paris, where he maintains collaboration with Hans Brettel and Francoise Vienot on research that is related to his color perception and visual adaptation model.

D. Kewley-Port has just finished her tenure as Associate Editor for *Speech Processing and Communication Systems of the Journal of the Acoustical Society of America.* She referees grant proposals for NSF and has served as a member of several NIH review panels. She also reviews manuscripts for *The Journal of Speech and Hearing Research, IEEE Transactions on Acoustic, Speech and Signal Processing, and Computer Users in Speech and Hearing.*

G. Kidd is a member of the American Psychological Society, the Acoustical Society of America, the International Society for Ecological Psychology, and an associate member of the Psychonomic Society. He has reviewed manuscripts for *Journal of Experimental Psychology: Human Perception and Performance, Language and Speech, Journal of the Acoustical Society of America, and American Journal of Psychology.*

D. P. Maki is a member of the American Mathematical Society, the Society for Industrial and Applied Mathematics, and the Acoustical Society of America and is a Governor of the Mathematical Association of America.

D. B. Pisoni is director of the Speech Research Laboratory at Indiana University. He serves on the editorial boards of *Computer Speech and Language and Speech Technology.* He is a recipient of the Jacob K. Javits Neuroscience Investigator Award (1987-1995).

R. F. Port is a member of the Linguistic Society of America, the Acoustical Society of America, the Association for Computational Linguistics, and the International Neural Network Society. He reviews manuscripts for the *Journal of the Acoustical Society of America, the Journal of Speech and Hearing Research, Perception and Psychophysics, and the Journal of Phonetics.*

D. E. Robinson continues to serve as a scientific advisor to CHABA and on the Science Advisory Board of the Parmly Hearing Institute, Loyola University, Chicago. He has reviewed papers for the *Journal of the Acoustical Society of America, the Psychological Bulletin, and Developmental Psychobiology.*

R. A. Suthers is on the editorial board of Experimental Biology and is a reviewer for the *Journal of Comparative Physiology, Ethology, Animal Behavior, Science, Behavioral Ecology & Sociobiology, and the Canadian Journal of Zoology.* He has been an invited lecturer at numerous national and international symposia.

L. N. Thibos serves as editorial reviewer for *Optometry and Vision Science* and *Vision Research*, and is Topical Editor for "Clinical Vision and Visual Optics", *Journal of the Optical Society of America.* He is grant reviewer for the Air Force Office of Scientific Research, the National Science Foundation and the National Health and Medical Research Council of Australia. He is a member of the national program committee for the annual meeting of the American Academy of Optometry.

J. T. Townsend recently finished his tenure as Editor of the *Journal of Mathematical Psychology*, as well as his term on the Executive Board of the Society of Mathematical Psychology. He previously served as President of the Society of Mathematical Psychology. He continues to serve as Associate Editor of *Journal of Mathematical Psychology* and is a member of many professional societies including: *Psychonomic Society, Society for Mathematical Psychology, Society for Judgment and Decision Making, International Neural Network Society, and Mathematical Association of America.* He serves as an editorial consultant and reviewer for a number of journals and granting agencies. Dr. Townsend was recently awarded a prestigious James McKeen Cattell Sabbatical Award for the academic year 1992-1993.

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3. Espinoza-Varas, B. and Watson, C.S. (1987). Perception of complex auditory patterns by humans. In S.H. Hulse and R.J. Dooling (eds.), *The Comparative Psychology of Complex Acoustic Perception.*

4. Espinoza-Varas, B. (1987). Involvement of the critical band in identification, perceived distance, and discrimination of vowels. In M.E.H. Schouten (ed.), *The Psychophysics of Speech Perception.* M. Nijhoff, The Netherlands, 306-313.

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59. Applegate, R.A., Bradley, A. and Zillio, C. (1990). See 7 micron capillaries in your own eye. Presented at the Annual Meeting of the Optical Society of America, November.

60. Applegate, R.A., van Heuven, W.A.J, Bradley, A. and Zeffren, B.S. (1990). Are current laser protocols endangering the fovea? Annual meeting of the Association for Research in Vision and Ophthalmology, May.

61. Applegate, R.A., Bradley, A. and van Heuven, W.A.J. (1990). Zapping the retinal point of fixation? Presented at the annual meeting of the American Academy of Ophthalmology, November.

62. Bingham, G.P. & Gutjahr, E.C. (1990). Perceiving the size of trees: An inkling of a solution

to the scaling problem in event perception. An invited paper presented at a meeting of the *Midwestern Psychological Association* in Chicago, Il, May 4th.

63. Bingham, G.P. and Muchisky, M.M. (1990). Center of mass perception. A paper presented at a meeting of the International Society for Ecological Psychology at the Beckman Institute, University of Illinois, Urbana, Il, May 22.

64. Bingham, G.P. & Gutjahr, E.C. (1990). Perceiving the size of trees: Reducing the problem of size perception to a problem of form perception. A paper presented at a meeting of the *International Society for Ecological Psychology* at the Beckman Institute, University of Illinois, Urbana, Il, May 22nd.

65. Bradley, A., Zhang, X. and Thibos, L.N. (1990). Experimental estimation of the chromatic difference of magnification of the human eye. *Invest. Ophthal. Vis.* Sci., **31** (suppl.), 493.

66. Castellan, N.J., Jr. (1990). Decision Making: Processing Probabilistic Information. Presented to American Psychological Association, Boston, August.

67. Evans, P.M. (1990). Crossmodal pattern perception. Presented to the Psychonomic Society, New Orleans, LA, November.

68. Gasser, M. (1990). Reduplication and simple recurrent networks. First Midwest Connectfest, Bloomington, IN, November.

69. Gasser, M. and Lee, C.-D. (1990). A short-term memory architecture for learning morphophonemic rules. Third Conference on Neural Information Processing Systems, Denver, November.

70. Humes, L.E. (1990). Nonauditory factors affecting noise-induced hearing loss. NIH Consensus Conference of Noise-Induced Hearing Loss, Bethesda, MD.

71. Humes, L.E. (1990). Peripheral factors underlying the speech-recognition difficulties of hearing-impaired elderly. American Academy of Audiology, New Orleans, LA.

72. Humes, L.E. (1990). Prescribing gain characteristics of linear hearing aids. Vanderbilt/VA Symposium on Hearing Aids, Nashville, TN.

73. Humes, L.E. (1990). Loudness perception by the hearing-impaired elderly. CHABA Conference on Hearing and Aging, National Academy of Sciences, Washington, DC.

74. Humes, L.E. (1990). Application of the speech transmission index (STI) and articulation index (AI) to the hearing-impaired. Acoustical Society of America, San Diego, CA.

75. Kadlec, H., & Townsend, J. T. (1990, August). Testing separabilities and independence with signal detection analyses. Paper presented at *Twenty-third Annual Meeting of Society for Mathematical Psychology*, Toronto, Montreal.

76. Kewley-Port, D. (1990). Cross-disciplinary advances in speech science. Presented at The Future of Science and Service Seminar, ASHA National Headquarters, October.

77. Kewley-Port, D. (1990). Thresholds for formant-frequency discrimination in isolated vowels. *J. Acoust. Soc. Am.*, **87** (suppl.), S159. Presented at the 119th Meeting of the Acoustical Society of America, State College, PA, May.

78. Kewley-Port, D., Watson, C.S. and Maki, D. (1990). Small Business Innovation (SBIR) Funding: A case study in bringing a computer-based speech training aid into the marketplace. *J. Acoust. Soc. Am.*, **88** (suppl.), S196. Presented at the 120th Meeting of the Acoustical Society of America, San Diego, CA, November.

79. Kidd, G. R. and Watson, C. S. (1990). Detection of relative-duration changes in tonal sequences. *J. Acoust. Soc. Am.*, **88** (suppl.), S147.

80. Mendell, L. L. and Castellan, N. J., Jr. (1990). Search strategies in sequential decision making: Information accumulation, search termination, and information presentation effect. Presented to Midwestern Psychological Assocation, Chicago, May.

81. Pickel, K. and Castellan, N. J., Jr. (1990). Juror's evaluations of relevant and irrelevant eyewitness testimony. Presented to Midwestern Psychological Association, Chicago, May.

82. Port, R. (1990). Perceiving sound patterns in time. Presented at the Center for the Study of Language and Intelligence (CSLI), Stanford University, March 22.

83. Port, R. (1990). Toward dynamic representation of sound patterns in networks. Presented at the Phonology Laboratory, Department of Linguistics, University of California, Berkeley, March.

84. Port, R. (1990). Connectionist models of auditory pattern perception. Presented to Department of Computer Science, Butler University, Indianapolis, April.

85. Port, R. (1990). Connectionist models for auditory pattern recognition. Presented at Central Institute for the Deaf, St. Louis, MO, October.

86. Port, R. (1990). Dynamic representations in connectionist models for audition. Presented to Department of Computer Science, Washington University, St. Louis, MO, October.

87. Port, R. (1990). Grounding of auditory symbols by means of dynamic auditory memory. Presented to Society for Psychology and Philosophy, University of Maryland, June.

88. Suthers, R.A. and Hartley, R.S. (1990). Effect of unilateral denervation on the acoustic output from each side of the syrinx in singing mimic thrushes. *Society for Neuroscience Abstracts* **16**(2) , 1249.

89. Thibos, L.N., Zhang, X. and Bradley, A. (1990). Effect of ocular chromatic aberration on the

luminance modulation transfer function for white light in the reduced eye. *OSA Annual Meeting Technical Digest,* **15**, 148.

90. Thibos, L.N. (1990). The effect of ocular chromatic aberration on visual performance. Visual Science Symposium: Optical limits to visual performance. *Optom. Vis. Sci.*, **67** (suppl.), 167.

91. Thibos, L.N. (1990). Is the reduced schematic eye good enough?. Visual Science Symposium: Do we need a new schematic eye? *Optom. Vis. Sci.*, **67** (suppl.), 167.

92. Thibos, L.N. (1990). New methodologies for distinguishing between optical and neural losses in vision: The Second Monroe J. Hirsch Lecture on Vision Care. *Optom. Vis. Sci.*, **67** (suppl.), 83.

93. Thibos, L.N., Zhang, X., and Bradley, A. (1990). White-light modulation transfer functions of the reduced schematic eye. *Optom. Vis. Sci.*, **67** (suppl.), 56-57.

94. Thomas, R., & Townsend, J. T. (1990, August). Stochastic dependencies in parallel and serial models: Effects on systems factorial interactions. Paper presented at *Twenty-third Annual Meeting of Society for Mathematical Psychology*, Toronto, Montreal.

95. Wilkinson, M.O., Thibos, L.N. and Cannon, M.W. (1990). Contrast constancy: neural compensation for image attenuation. *Invest. Ophthal. Vis. Sci.*, **31** (suppl.), 323.

96. Ye, M., Bradley, A., Thibos, L.N. and Zhang, X. (1990). Effect of pupil apodization on apparent visual direction. *OSA Annual Meeting Technical Digest,* **15**, 91.

97. Ye, M., Bradley, A., Thibos, L.N., and Zhang, X. (1990). The role of the Stiles-Crawford effect in determining monocular visual direction. *Optom. Vis. Sci.*, **67** (suppl.), 57.

98. Zhang, X., Ye, M., Thibos, L.N., and Bradley, A. (1990). Retinal image contrast and the Stiles-Crawford Apodization. *Optom. Vis. Sci.*, **67** (suppl.), 57.

99. Zhang, X., Ye, M., Bradley, A. and Thibos, L.N. (1990). Stiles-Crawford effect improves defocused or aberrated retinal image quality. *OSA Annual Meeting Technical Digest,* **15**, 91.

1991

100. Anderson, R., Wilkinson, M.O., and Thibos, L.N. (1991). Psychophysical localization of the human visual streak. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 699.

101. Bingham, G.P. & Muchisky, M.M. (1991). Size perception in events. Presented at a meeting of the *International Society for Ecological Psychology* at Trinity College, Hartford, CT, October 19th.

102. Bingham, G.P., Muchisky, M.M. & Romack, J. (1991). 'Adaptation' to displacement prisms

is sensorimotor skill acquisition. Presented at a meeting of the Psychonomic Society, San Francisco, CA, November 24th.

103. Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping. A paper presented at the Conference on Human Error sponsored by the Institute for the Study of Human Capabilities at Indiana University, March 22nd.

104. Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping: A GSD problem. Presented at the *6th International Conference on Event Perception and Action,* Amsterdam, August 29th.

105. Bingham, G.P. (1991). The identification problem in visual event perception. Presented at a Conference on Dynamic Representation in Cognition, Indiana University, Bloomington, IN, November 16th.

106. Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at a meeting of the Association for Research in Vision and Ophthalmology, Sarasota Springs, Florida, April 30th.

107. Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at the *6th International Conference on Event Perception and Action,* Amsterdam, August 30th.

108. Bingham, G.P. (1991). Why does optical pattern never look flat? (Or the demise of 'efference copy'). Presented at the Department of Psychology, Indiana University, Bloomington, IN, October 2nd.

109. Bradley A., Rahman, A., Soni, P.S. and Zhang, X., (1991) Through-focus measures of vision with 2-zone and diffractive bifocal contact lenses. *American Academy of Optometry Symposium on Simultaneous Bifocal and Multifocal Vision.*

110. Bradley, A., Thibos, L.N., Zhang, X., and Ye, M. (1991) The effects of ocular aberration on visual performance for displayed achromatic and chromatic information. In: *Digest of Technical Papers,* Society for Information Display, **22**, 304-307.

111. Bradley, A. and Applegate, R. A. (1991). Clinical value of the vascular entoptoscope. Presented at the Fergus Fest in Cambridge, England.

112. Bradley, A., and Thibos, L. N. (1991). Incorporating the eye's optics into an applied model of detection and identifiacation of objects: Presented to the *Armstrong Laboratory Advisory Group Conference* in San Antonio, TX.

113. Evans, P. M. and Craig, J.C. (1991). Identifying the direction of simulated movement on the skin. The effects of an irrelevant stimulus. Presented to the Acoustical Society of America, Baltimore, MD, May.

114. Evans, P.M. and Craig, J.C. Tactile attention and response competition. Presented to the Psychonomic Society, San Francisco, CA, November, 1991.

115. Gasser, M. (November, 1991) Phonological performance and sequential networks. Panel on Connectionism and Phonology. Second Annual Midwest Connectfest, Columbus, OH.

116. Kewley-Port, D. and Watson, C.S. (1991). 'Thresholds for formant-frequency discrimination of vowels in consonantal context." *J. Acoust. Soc. Am.*, **89**, 1996.

117. Mora, Juan Pablo, Robert F. Port and Catharina de Jonge (1991) Cross-language word identification using durational cues only. Paper presented at the Acoustical Society of America. *Journal of the Acoustical Society of America* **90**, (A) 2253.

118. Merrill, John W. L. and Robert Port (1991) Fractally configured neural networks. *Neural Networks* **4**, 53-60.

119. Nozawa & Townsend, J. T. (1991). Analyses of reaction times obtained in the redundant target paradigm: Evidence for parallel processing. Twenty-fourth Annual Meeting of Society for Mathematical Psychology, August, 1991, Bloomington, IN

120. Port, Robert F. and van Gelder, T. (1991). Dimensions of difference: compositional representations in AI and connectionism. *Cognitive Science Research Report*, **40**, IU Cognitive Science Program, Indiana University, Bloomington, IN.

121. Port, Robert and Timothy van Gelder (1991) Representing aspects of language. *Proceedings of the Cognitive Science Society*, **13**, (Lawrence Erlbaum, Hillsdale, NJ) pp. 487-492.

122. Thibos, L.N. and Bradley, A. (1991). The limits to performance in central and peripheral vision. In: *Digest of Technical Papers, Society for Information Display*, **22**, 301-303.

123. Thibos, L.N., Zhang, X., and Bradley, A. (1991). The chromatic eye: A new model of ocular chromatic aberration. *Technical Digest on Ophthalmic and Visual Optics*, **2**, ThB1 1-4.

124. Thibos, L.N., Bradley, A., Wilkinson, M., and Cannon, M. (1991). New evidence for human errors in the perception of spatial patterns and contrast. Conference on Human Error, sponsored by Indiana Institute for the Study of Human Capabilities (March 20-22, 1991), 15-16.

125. Thibos, L.N., Zhang, X., Bradley, A. and Ye, M. (1991). Color-contrast modulation transfer functions and the effect of ocular chromatic aberration. *Invest. Ophthal. Vis. Sci,*. **32** (suppl.), 1210.

126. Thibos, L. N., Bradley, A. (1991). Fun with interferometers. Presented at the Fergus Fest in Cambridge, England. *Opthalmic Physiological Optics.*

127. Townsend, J. T., (1991) Invited Presentation at IU Institute for the Study of Human Capabilities, Conference on Human Error: A New Theory of Ordinal Decision Making

in Statistical Inference. March 22, 1991; Bloomington, IN.

128. Wilkinson, M.O., Thibos, L.N., and Bradley, A. (1991). Neural basis of scotopic acuity. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 699.

129. Watson, C. S., Kidd, G. R., & Foyle, D. (1991). The proportion-of-the-total-duration (PTD) rule for auditory pattern discrimination. Presented at the third annual convention of the American Psychological Society. Washington, D.C., June 1991.

130. Zhang, X., Thibos, L.N., Bradley, A., and Ye, M. (1991). Modelling effects of defocus on human eyes with large pupils. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 1211.

1992

131. Bingham, G.P., Romack, J.L. & Buss, R.A. (1992). "Adaptation" to displacement prisms is sensorimotor skill acquisition. Presented at the Conference on Human Error sponsored by the Institute for the Study of Human Capabilities at Indiana University, Bloomington, IN, March 26th.

132. Bingham, G.P. & Muchisky, M.M. (1992). Perceiving size in events. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 1st.

133. Bingham, G.P. (1992). Perceiving the size of trees via their form. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 15th.

134. Bingham, G.P. (1992). Perceiving the size of biological objects: Form as information for scale. A paper presented at a meeting of the *Association for Research in Vision and Ophthalmology*, Sarasota Springs, Florida, May 5th.

135. Bingham, G. P. (1992). Perceiving the size of trees via their form. Presented at the *14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 30th.

136. Bingham, G.P. (1992). Form as information about scale: Perceiving the size of trees. Presented at a meeting of the *Psychonomic Society*, St. Louis, MO, November 13th.

137. Blank, D., & Gasser, M. (1992). Grounding via scanning: Cooking up roles from scratch. *Fourth Annual Conference of the Midwest Artificial Intelligence and Cognitive Science Society.*

138. Bradley, A., (1992) Hi-tech bifocal contact lenses: a marriage of holography and vanity creates a human factors nightmare. *Human Error Conference, Indiana University.*

139. Craig, J.C., & Rinker, M.A. (1992) Effect of hand position on perception of tactile stimuli. Presented to *Psychonomic Society*, November, 1992.

140. Evans, P.M., & Florl, L.K. (1992) The perception of target and nontarget stimuli presented to

the forearm. Presented to *Psychonomic Society*, November, 1992.

141. Gasser, M., & Celis, N. (1992). Towards a connectionist approach to transfer in machine translation. *Fourth Annual Conference of the Midwest Artificial Intelligence and Cognitive Science Society.*

142. Gasser, M. (March, 1992). Learning syllable representations in sequential connectionist networks. *Workshop on the Cognitive Science of Natural Language Processing*, Dublin, Ireland.

143. Gasser, M. (December, 1992) Grounding structure. Workshop on Approaches to Symbol Grounding, *Neural Information Processing Systems Post-Conference Workshops*, Vail, CO.

144. Why are nominal terms learned faster than dimensional adjectives? (with Linda B. Smith). *17th Annual Boston University Conference on Language Development*, Boston, October, 1992.

145. Muchisky, M.M. & Bingham, G.P. (1992). Perceiving size in events via kinematic form. Presented at the *14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 31st.

146. Romack, J.L., Buss, R.A. & Bingham, G.P. (1992). "Adaptation" to displacement prisms is sensorimotor learning. Presented at the *14th Annual Conference of the Cognitive Science Society*, Bloomington, IN, July 31st.

147. Watson, C. S., & Kidd, G. R. (1992). Psychoacoustics and psychophysics of auditory warnings and displays. Presented at the *Conference on Human Error*, Indiana University, Bloomington, Indiana, March 1992.

1993

148. Bingham, G.P. & Romack, J.L. (1993). Targeted reaching with perturbation of visual direction. Presented at the *18th Annual Interdisciplinary Conference*, Jackson Hole, Wyoming, January 17-22.

149. Bingham, G.P. (1993). Spatio-temporal information in visually guided reaching. Presented at the conference sponsored by the *Office of Naval Research on Neural Representations of Temporal Patterns* at Duke University, Durham, North Carolina, May 1st.

150. Gasser, M. (March, 1993). A neural network model of developmental changes in naming behavior (with Linda B. Smith). *60th Meeting of the Society for Research in Child Development*, New Orleans.

151. Guth, S.L. (1993). Unified model for human color perception and visual adaptation, II.

Presented at SPIE/IST conference, San Jose, CA, February, 1993.

152. Guth, S.L. (1993). ATD model for color and adaptation. Paper to be presented at *ECVP (European Conference on Visual Perception)* Ediburgh, Scotland, August, 1993.

153. Guth, S.L. (1993). ATD model for color appearances, discriminations and adaptation. Paper to be presented at *Euro Display '93*, Strassbourg, France, September, 1993.

154. Port, Robert, Catherine Rogers , Charles Watson and Gary R. Kidd (1993) The effects of training method on frequency discrimination of individual components of complex tonal patterns. *J. Acous. Soc. Amer.* Presented at Spring Meeting (Ottowa) of ASA.

155. Townsend, J. T., (1993) Invited Address by Jerome R. Busemeyer of Purdue University: A decision Field Theory Account of Some "Paradoxical" Findings from Decision Research.